SILICON CHIP

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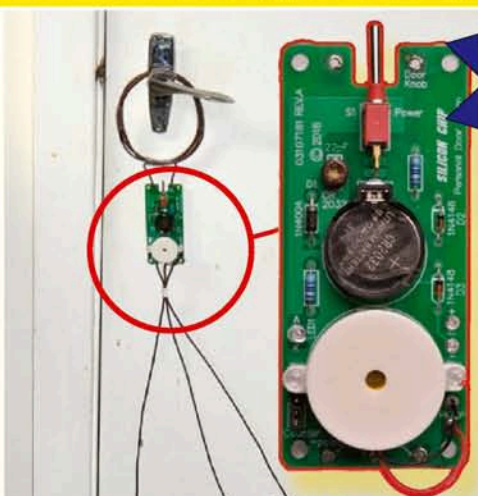

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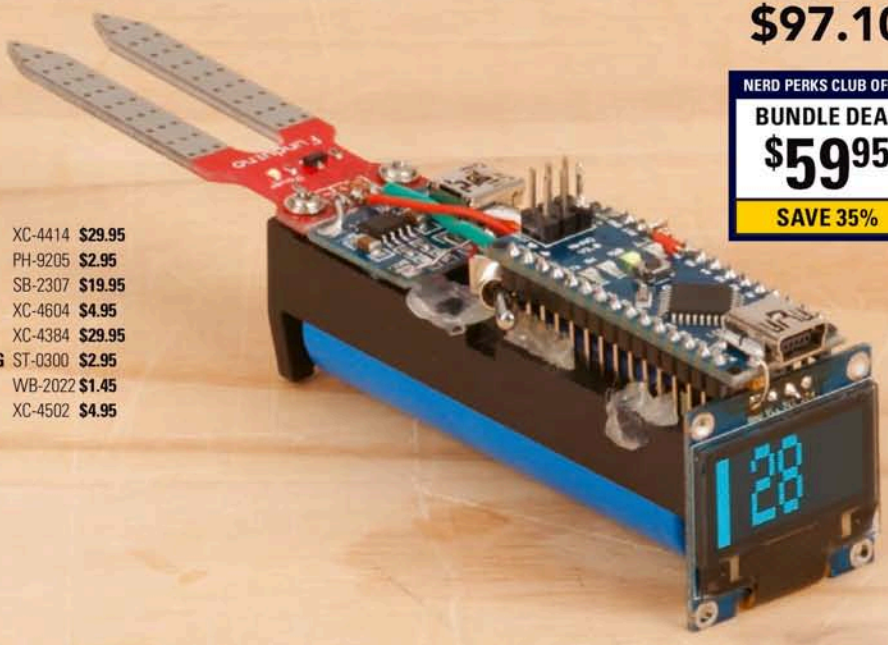

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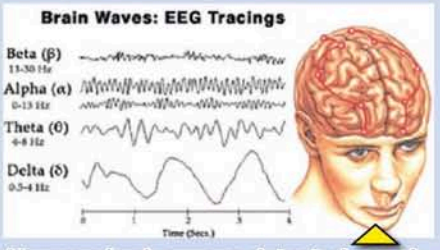

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Editorial Viewpoint

New base-load power stations are crucial

Despite the fact that many people have this romantic view that Australia can continue to invest heavily in renewable energy sources such as wind and solar, we desperately need new base load power stations. Without a reasonable number of base load power stations, we will inevitably be subject to serious blackouts. Not only is this irritating for domestic consumers, it ultimately makes much of our heavy industry unviable. As existing coal-fired power stations are decommissioned, they must be replaced with new ones.

So what are the options being discussed? With nuclear stations off the agenda, only two appear to be on the list; so-called HELE (High Efficiency Low Emissions) coal-fired and the much criticised Snowy Hydro2.0 hydroelectric option which is not base load but a peak load proposal. Taking the latter option first, most of the criticism of this proposal is just bog ignorance, with people scorning it because it delivers less electricity than is used to pump up the dams. Well in the real world, this is the case with all rechargeable batteries whether they run your smart phone, your car battery or whatever.

But Snowy Hydro2.0 is a very good (rechargeable battery) proposal which will store and use excess renewable energy, then release it at peak loading times. You can read more about pumped hydroelectricity schemes in the January 2017 article at siliconchip.com.au/Article/10497

HELE coal fired power stations should definitely be built in Australia and construction needs to start as soon as possible. We have heaps of coal and it makes no sense at all that we are one of the world's biggest exporters of steaming coal but we are shutting down our cheapest power stations while China and other countries are building new HELE stations as fast as possible – to use that very same coal!

However, coal mining does have serious environmental consequences whether it is open-cut or underground, and open-cut mines need huge areas to be remediated at vast expense when the mines reach the end of their life.

But there is another fossil fuel option that does not even seem to be on the table: combined-cycle gas-fired power stations. Australia has a few, such as Darling Downs in Queensland, the Ichthys LNG project in Perth (not used for base-load to consumers), Tallawarra in NSW and Pelican Point in Adelaide, South Australia.

Combined-cycle gas-fired power stations are even more efficient than HELE coal-fired stations, mainly because they operate at higher temperatures and use waste-heat from the gas turbines to generate steam for a turbo-alternator. And they have a major advantage in that they cause very little environmental damage and there is far less need for remediation at the end point for a gas field.

Mind you, they do have drawbacks and the main one is that due to the very high operating temperatures in the main turbines of a combined-cycle plant, the plant typically has an operating life of no more than 30 years. (See: siliconchip.com.au/link/aaki). Coal plants last much longer than that; 50 years is not unheard of. Regardless of that, all three options should be proceeded with. Otherwise, Australia's economy will be in dire straits.

This will be my last editorial for SILICON CHIP. After 31 years, I am handing the magazine over to Nicholas Vinen. I can assure you that the magazine format will stay much the same and there will be no "dumbing down" of the editorial content. On the other hand, perhaps some readers will be happy to see me finally put out to pasture and no longer able to write those inflammatory anti-global warming Publisher's Letters, when I should have been concentrating on more prosaic topics more closely related to electronics.

Leo Simpson

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MAILBAG – your Feedback

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Cassette article brings back memories

The article on the Philips Compact Cassette in the July 2018 issue of SILICON CHIP certainly brought back memories for me.

I still remember using blue hexagonal Bic Crystal ballpoint pens to occasionally wind back the tape wheels on the cassette when the tape became slack.

I also remember breaking the tab off the cassette to prevent accidental recording, which we also did with VHS cassettes. We used isopropyl alcohol or a cleaning cassette to clean the heads of the cassette player.

And how can I forget Cliff Richard's song from the 80s, "Wired For Sound", dedicated to the Walkman?

I still have a Stereo Midi System which can play cassettes and CDs; many people have tossed theirs; they may find that they want them back again, as they find cassettes during cleanups etc.

I enjoy reading these special features as they bring back many memories.

Peter Casey,
West Pennant Hills, NSW.

Cassette article omitted 8-track history

I just finished reading Ian Batty's excellent article on the Philips Compact Cassette in the July issue but I am a little surprised that he did not mention the 8-track cartridge (Stereo 8) which came after the reel-to-reel machines and before the Compact Cassette.

The 8-track and the Compact Cassette, in fact, were competitors at the time and although (I believe) the 8-track was superior in quality due to the use of 6mm tape, the compact cassette won out due to its smaller volume. You could pack four Compact Cassettes into the same volume as one 8-track cartridge.

Stereo 8 was also innovative in its use of a single spool of tape fed from the centre, out around a capstan and back onto the outside of the spool. Incidentally, the plastic 8-track case was also used to house ROM packs in early computers. My Exidy Sorcerer computer uses such ROM Packs.

Perhaps an article on the introduction and demise of the 8-track would make good future reading.

Brian Smart,
Myrtleford, Vic.

Hot water temperature and Legionella bacteria risk

I just finished reading your response to the letter titled "Hot Water System article criticism", in the Mailbag section of the March 2018 issue (page 11). In your response, you mentioned "scalding from the hot water tap over laundry tubs".

I don't know about anywhere else in Australia but in Victoria, the Victorian Building Authority (VBA) indicates that the laundry and kitchen temperatures don't have to be lowered to 50°C as for the sanitary areas. See the information at the following link: siliconchip.com.au/link/aak8

Roderick Wall,
Mount Eliza, Vic.

Leo responds: thanks for sending the link regarding hot water delivery temperatures. I found the section on avoiding dead ends (to prevent bacterial growth) most interesting.

However, it does not contradict my contention that a hot water tap in a laundry could deliver scalding water and that a tempering valve could be fitted; in fact, it reinforces my point. I am not suggesting that a tempering valve should be fitted to reduce the water temperature delivered for washing. Clearly, that would not be desirable.

An off-grid power system for refrigerators

Your series of $LiFePO_4$ UPS articles in the May-July 2018 issues (siliconchip.com.au/Series/323) has prompted me to write in about a large off-grid solar

Decommissioning Nuclear power plants

The many articles by Dr David Maddison you have published over the last few years have been well-researched and prepared, making for very interesting reading. That includes the recent article on Generation IV Nuclear power reactors in March 2018 (siliconchip.com.au/Article/10996).

I would like to read an equally well-researched and prepared article (or series of articles if necessary) by Dr Maddison on the decommissioning of nuclear energy plants, including:

- the procedures for reforming and reclaiming nuclear fuel elements (rods)
- the removal and storage of "waste" fission products
- the dismantling of the reactor and associated irradiated structures
- the reclamation of a nuclear energy power site so it can be released for public use

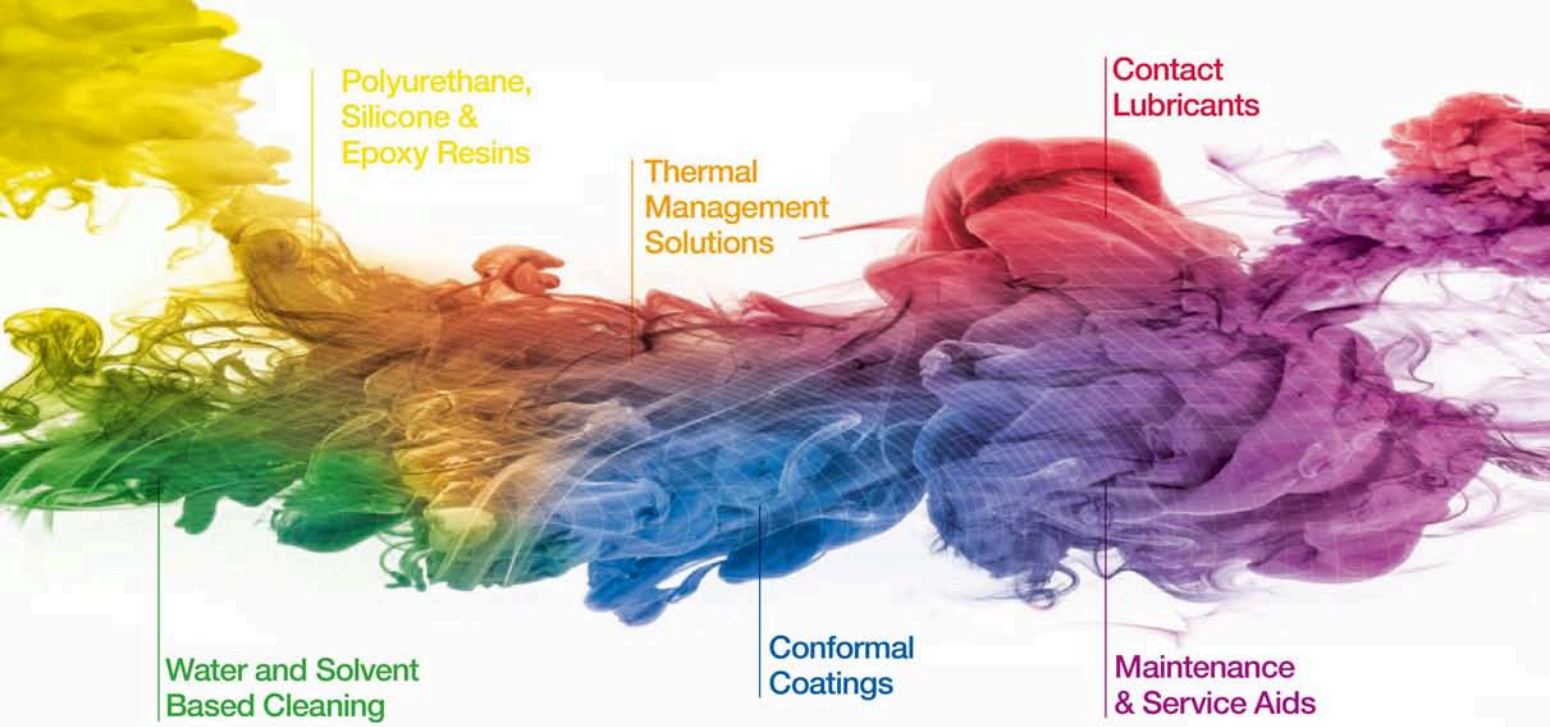
I am particularly interested in how long each of these steps takes. I would also like to hear his opinion on the source of, and the environmental problems presented by, the increase (approx 43%) of atmospheric CO_2 from pre-industrial times to the present (280ppm to greater than 400ppm).

Thanks for your consideration.

Col Hodgson,
Mount Elliot, NSW.

Response: thanks for your suggestion. That would certainly make for an interesting article but it is a really big topic and one which will require a lot of research.

Also, we are concerned that these topics mostly involve chemistry and physics, with relatively little electronic or electrical involvement. However, on the basis that it does relate to electricity generation, we will consider it.



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system that I built using similar components. It is intended to provide enough power to keep my refrigerators running through long blackouts. I was prompted to build this when I discovered that a grid-tied inverter would shut down during a blackout.

I am using a Giandel 2000W (4000W peak) inverter, which is powered by a 12V battery bank that is kept charged by solar panels. The solar panels are connected in series to produce 300V DC. My plan was to feed this to a 12V/20A mains battery charger (Dynahub HC-20A), which I got from eBay for about $45.

The problem was that the charger contained a small mains transformer to run some of its electronics and this meant it would only run from an AC supply. My solution was to remove the transformer, bridge rectifier and 15V 3-terminal regulator and replace them with a small encapsulated switchmode supply: a 2W-rated MeanWell unit with a 15V DC output. This will run from high-voltage DC.

I attached the encapsulated supply to the board using double-sided tape, where the mains transformer used to be.

The reason I am using an inverter with such a high power rating is to ensure it can provide the large start-up current of my two refrigerators. Once they are running, they draw only a few hundred watts at most.

It would be good to use a large 12V lithium-ion or $LiFePO_4$ rechargeable battery like you used in the UPS project but these are about $500 at present. So I am using a large car battery at the moment. It is sufficient to run the fridges for several hours; blackouts in my area do not typically last longer than that.

Roger Sanderson,
Fig Tree Pocket, Qld.

Who will remind the reminders?

I just read the July 2018 Recurring Event Reminder project (pages 68-71) and note that the first thing that stands out is that it appears to be a digital version of the old (analog) string tied around a finger and as such comes with the same problem – how does one remember what the device was set to remind one of in the first place?

One idea that comes to mind, if it is finally built into a small plastic case, would be to write on a sticker and stick this onto the front of the case. However, there must be better ways of doing this.

However, that aside, the basic project looks very interesting.

Paul Myers,
Karabar, NSW.

Nicholas responds: it depends on what sort of memory problem you have. I almost never forget an event; it's just that I usually remember it several hours after it was supposed to happen! So for me, such a reminder could be quite useful, simply to jog my memory at the right time.

We think your idea of sticking some kind of a label on the unit is a good one but there are other options such as using post-it notes or writing tasks on a nearby pad, blackboard or whiteboard. These could be thrown away, crossed out or erased once the tasks are completed.

Advice on protection for micro inputs

There are lots of applications where electronics of all varieties might need to interface with the real world in less than ideal environments – an Arduino or Raspberry Pi in a vehicle would be a good example.

Obviously, some level of protection is required on both the inputs and the power supply, although many examples can be found where little or no such protection is provided.

How about an article describing what protection might be required in these sorts of environments, and the options available to provide it? There needs to be a reasonable approach as to what is ideal versus what is practical or adequate and using parts that are fairly readily available and do not occupy the entire available real estate.

As usual, there is a plethora of information available on the 'net, where everyone is an expert, with arguments for and against various approaches which really only adds to the confusion. What do you think?

Trevor Queale,
Toowong, Qld.

Response: take a look at some of our circuit designs which involve interfacing micros to external devices, especially those designed for automotive environments. The protection we provide is sufficient for good reliability without involving too many components.

For example, see the Temperature Switch Mk2 in the June 2018 issue (siliconchip.com.au/Article/11101).

Generally, all you need to protect a micro pin is a series resistor of around 1kΩ. Higher values can be used as long as the signal frequency is low (for digital signals) or the exact voltage level is not critical (for analog signals).

The micro's internal ESD clamp diodes prevent the input pin from being pulled too far outside the micro's supply range while the series resistor limits the clamp current to a safe level.

You will also see that in that design that for the 12V supply input, we have a 100µF bypass capacitor followed by a 47Ω series resistor and a second capacitor (10µF) which has a 16V zener diode across it. This then feeds the input of the 5V regulator.

These components are sufficient to prevent damage to the regulator from brief spikes in excess of ±100V (eg, load dumps) and allow the micro to operate normally even with quite a dirty 12V power supply.

Monitoring home electricity usage

Thanks to Andrew Gross and Al Lockyer or their replies in the February 2018 issue (Mailbag, pages 8-11). These were in response to my earlier letter regarding monitoring home energy usage, which was published in the August 2017 issue (page 4).

In fact, I had already chosen to use a commercial solution called "engage" (https://engage.efergy.com/) although I would have much preferred an open-source solution. The product that I chose uses three clamp meters to measure the mains current flowing in each phase connected to the home and infers the overall energy usage from these readings.

Each clamp meter is connected to a separate, battery-powered transmitter and a small receiver is attached to my router. The data is uploaded to a website that is maintained by the vendor, which I can then access remotely.

The vendor's website has some rather fancy displays and importantly allows the user to download reports of the captured data aggregated to either the minute, hour or day. A separate report is generated for each calendar month. The data is downloaded as CSV (comma-separated values) files and is easily imported into a spreadsheet for in-depth analysis.

I have been able to make some useful observations with the data captured thus far although I have an ultimate plan to capturing one year's worth,

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which should happen by mid-July. One thing that I wasn't aware of is that my electric oven is the only device attached to the third phase; everything else including the reverse-cycle air conditioning is on phases one and two.

In comparing the recorded usage to my energy retailer's usage, I have noticed a variance of about 11% which is greater than the vendor's specified error value. I have queried this with the vendor but not received a satisfactory response.

The vendor's website allows a user to set the voltage for each phase. In my case, the actual voltage on each of the three phases is normally 250±2VAC. The value for each phase is displayed on the electricity meter in my meter box and I have confirmed the values with a multimeter.

To compensate for the variance between the metered and measured usage, I have had to adjust the voltage setting on the website to 220VAC.

The vendor's website also allows the user to input a simple tariff to calculate the cost of energy used. However, this would be no good for energy plans which have varying (time-of-day) tariffs.

Once I have a full year's worth of data, I will hopefully be able to make a more informed decision with respect to possibly buying photovoltaic panels.

Walter Hill,
Mount Pleasant, WA.

Neutral and Earth should be connected to the same bus bar

I read the letter in the June issue regarding the electrician who was electrocuted after the smoko break ("Proposal for reducing sparky electrocutions", pages 4-5). I cannot understand why there is an interconnection between the Neutral and Earth bars that can be broken.

My home board has one bar and the incoming Neutral and home ground are attached to one end with two screws, while the other home Neutral connections are made with single screws on the same bar (see photo below). The bar is suitably and clearly marked. What the bar to the left is for I have no idea.

I also agree in general with Gary Jackson's letter on page 5, where he complains that engineers need to get electricians to do simple mains wiring jobs.

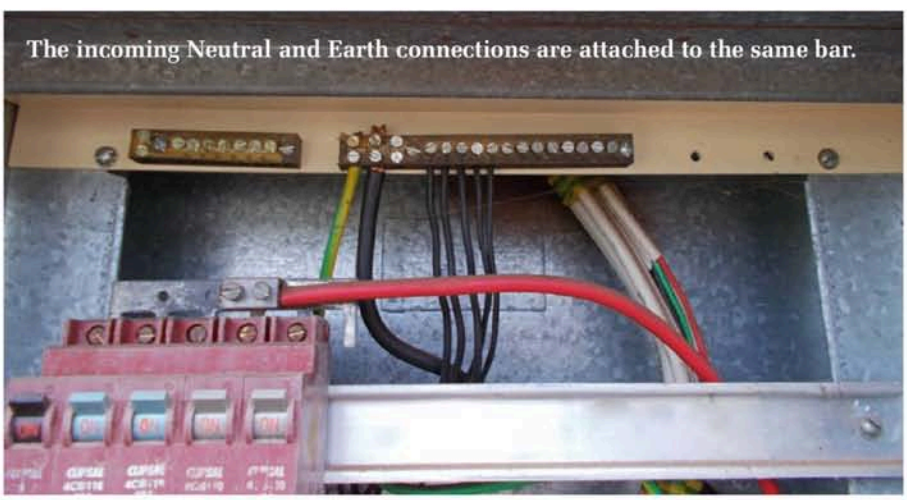
I agree that suitably trained technical types can do simple wiring jobs such as moving a GPO with little difficulty. I hold a Diploma of Civil Engineering and part of the coursework related to hands-on mains voltage work, in a laboratory situation.

That reminds me of one time I got a bit of a fright. I was helping a friend to move a GPO to the opposite side of a wall in his shed. We plugged a light into the socket and switched off the breaker in the sub-board, to verify that the circuit was well and truly off while we did the work.

Using my volt meter, I then checked across each pair of GPO sockets connections (A-N, A-E and N-E) to determine if the circuit breaker was in the Active or Neutral line. It was correctly wired.

Still being cautious and with good lighting available, I disconnected the GPO and placed some insulation tape on the Active wire. I am a chicken and don't like the idea of being zapped!

I then relocated the GPO bracket to the other side of the column and also relocated the wires.



The incoming Neutral and Earth connections are attached to the same bar.

Just prior to reconnecting the GPO I inadvertently touched the bare Neutral wire with the back of my hand. It had no effect on me but suddenly the shed went dark. Luckily, I had a rechargeable torch on hand.

So apparently there was an RCD somewhere. It certainly wasn't in the shed's sub-board. All of the house circuits were dead. A search for the main board took place and an RCD was found and reset. Also the clocks!

I have measured a few volts on Neutral wires relative to Earth before; apparently, in this case, the N-E potential was high enough that sufficient current could flow from Neutral to Earth through my body to trip the RCD; or perhaps I somehow induced a current spike that tripped the RCD.

Finally, I would like to say that I liked the article on the Astor GP/PS Hybrid Portable radio in the June issue (siliconchip.com.au/Article/11116). Some years ago, Rodney Champness provided me with a 240VAC to 90V+1.5V DC power supply circuit, so that I could bring my father's Astor KP radio back to some form of life; unfortunately, not as a portable.

Some time ago, I had a Grundig portable with a similar number of components to the Astor but in a case about one-quarter of the volume. Unfortunately, I consigned it to the tip some years ago.

Ray Smith,
Hoppers Crossing, Vic.

UPS project welcome

Thank you for another interesting May issue of SILICON CHIP. The articles on Drone Air Taxis and the gut capsules were good general reading but it was hard not to notice the UPS project. The font size of "DIY UPS!" on the front cover must be only one less than the "SILICON CHIP" title.

I remember suggesting such a project to you in my April letter last year and I thought that it had been assigned to the dustbin. But it seems that I wasn't the only one who suggested the project.

I am glad that you have proceeded with the project because you have provided the answer to why most UPS designs have multiple relays. Having dismantled a very large number to retrieve expensive and/or hard-to-get components, most of them have contained at least three relays and normally four. A couple of nasty el-cheapo ones had only one change-over relay.

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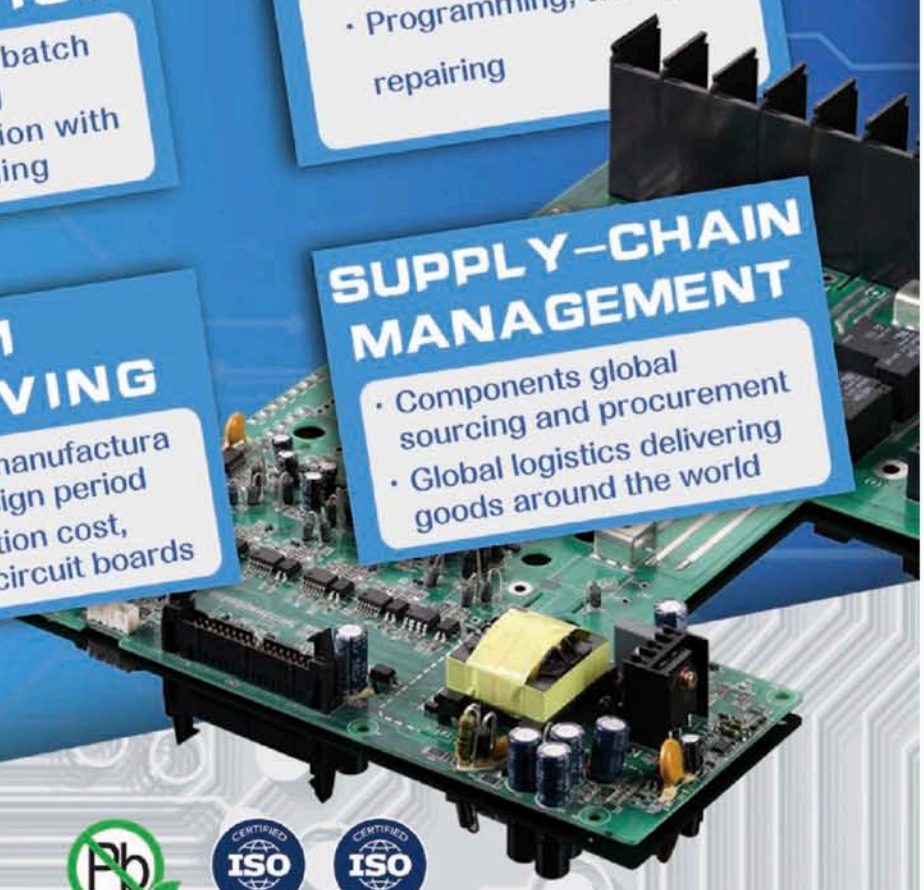

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It had not occurred to me that a single relay could be subject to voltages over 340V peak, that is, except for spikes etc. It will be interesting to see how well the project is received. It does have great potential.

George Ramsay,
Holland Park. Qld.

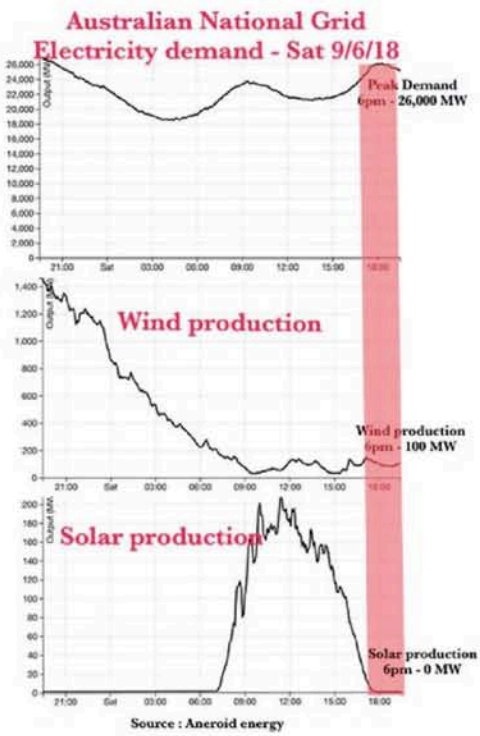
Response: Duraid came to us with the idea of doing a lithium-ion based UPS, based on his experience with using commercial UPSes on a large scale in cluster computing.

It may be possible to use one relay if it had a sufficiently high voltage rating. But since a voltage of either polarity could be present on the incoming mains line while the inverter is still providing power to the load, it's hard to imagine how a single standard (250VAC) mains-rated relay could do the job safely.

Weep for Australia's stupidity

Over the past decade, subsidies and hand-outs have resulted in the spending of around $50 billion of our nation's limited and precious capital on so-called "renewable" energy sources – solar and wind power. Untold billions more have also been spent to upgrade transmission lines to connect these to the grid.

For that money, we could have instead built 10 new HELE coal-fired power stations (which would have lowered CO_2 emissions) and had change left over to build 10 new Adelaide Hospitals (the most expensive hospital ever built in the world).



Yet this "investment" (or should I say "malvesment") has hollowed out the baseload generation of the nation, causing wholesale electricity prices to triple, and at times resulting in power having to be cut to our nation's aluminium smelters to avoid blackouts.

Yesterday at 6pm, when demand peaked at just over 26,000MW, that $50 billion spent on wind and solar was only providing 100MW (as shown in the chart). That's less than 0.4% of the total demand! It beggars belief. How could our nation waste so much money?

Rodney Champness,
Mooroopna, Vic.

High-speed recording of compact cassettes was tricky

I found Ian Batty's article on the Philips Compact Cassette (July 2018; siliconchip.com.au/Article/11136) to be comprehensive and reading it was a jog down memory lane for me.

I remember my first sightings of the little machine. My then boss at EMI Homebush, Arthur Cooper, exclaimed upon seeing it for this first time that it was "fearfully and wonderfully made" (Psalm 139:14).

In restoring many such machines over the decades, I found a special jig for setting the height of the U-shaped guides (intended for digital recording) most helpful in preventing tangled tapes.

A critical factor for maintaining HF response was to keep the azimuth right; with the player's use, this quickly drifted. It was normally adjusted using a sealed Phillips screw head via a hole in the case.

During the 60s through to early 80s, I believe factory-produced music tapes were recorded at a high speed. Unfortunately, because this pushed the bias frequency way up, AM radio transmitters in Homebush bay interfered with this process. I'm not sure how they solved it!

I remember that at EMI, we had an oven and refrigerator for extreme temperature tests of equipment, as well as machines for repeated mechanical tests.

Neville Snow,
Burwood, Sydney

Leo responds: The high-speed recording bias interference must have been a tricky problem to solve. Presumably, they could only cure it by doing the duplicating process in a shielded room. I remember that the EMI plant had a very large shielded room which was very effective.

An alternative to Visual Basic

I read with interest Keith Anderson's letter in the July 2018 issue regarding programming languages. He wrote (and you agreed) that Visual BASIC is clunky and difficult to use, yet neither of you offered a suggestion for an alternative, besides moving away from BASIC altogether (which can be a good choice).

But if one wished to learn to program for Windows using a version of BASIC, I can recommend Liberty Basic by Carl Gundel. It is approximately 98% compatible with "ye-olde" GW-BASIC, which many older readers would remember from the early days of the IBM-compatible computer.

But it also has Windows extensions to configure, open, handle and close various types of windows, and also has commands to allow the BASIC program to directly call Dynamic Link Library (DLL) routines, including the Windows Application Programming Interface (API) DLLs.

Admittedly, there are some disadvantages. You need to pay if you wish to create stand-alone applications (just under US$60, which is approximately AU$85) although you can still run programs in the Integrated Development Environment (IDE) with the unregistered free version.

Also, the programs are not fully compiled and must be run using an external Run Time Environment (RTE) program and its accompanying support files. This makes them slower to run than a fully compiled program and less convenient to distribute.

But the RTE is still very powerful and if you aren't asking it to perform very CPU-heavy tasks, it is quite fast enough for general usage. There is also an active support forum to help newcomers and long-time programmers alike. A trial version of Liberty Basic which can only run programs inside the IDE may be downloaded for free from www.libertybasic.com

The downloadable version can be upgraded with a registration code to allow it to compile programs to be run under the RTE.

Of course, C/C++ or assembly lan-

guage are better choices for mainstream programming but Liberty BASIC is still a good choice for a beginner to programming.

It teaches many of the necessary principles involved in any type of programming while using a syntax which is easier for a beginner to understand than either C or assembler.

Jonathan Waller,
Bairnsdale, Vic.

Question regarding 3G mobile data

On reading the article on the "Home & Farm Water Tank Level Meter" project (February 2018; siliconchip.com.au/Article/10963), which uses WiFi to upload to the cloud, it brings up something which has been on my mind.

I have a Solar Analytics power monitoring system which uploads the household power usage and solar panel generation measurements to the cloud and then to my account. It does this at five-second intervals, 24/7.

I have been told that the equipment uses a 3G SIM card but it doesn't make a phone call. I do pay a small annual fee for this feature; around $6 per month.

Would the explanation of how this works be worth an article? Perhaps you could include a description of the Telstra Narrowband system.

David Bruce-Steer,
Artarmon, NSW.

Response: we aren't sure that we could justify an article on this as it is a well-established technology.

Voice calls on the GSM (2G) phone system consisted of a series of compressed digital data packets. To reduce overhead, since all the packets for a given call are to the same destination, it was designed as a "circuit switched" network, ie, a "circuit" is established, all the packets travel over that circuit, then at the end of the call, the "circuit" is terminated.

The GPRS system was developed as a way to expand the GSM phone system for data traffic. This resulted in a "2.5G" system which was a hybrid circuit-switched/packet-switched network. Data packets could then be individually routed to their destination. This scheme was kept for the 3G network, although it was designed with data transmission in mind from the start, meaning higher data rates and less overhead.

Your power monitoring system will simply be generating one data packet every five seconds. The data transmitted will easily fit into a single packet (normally 128 bytes).

Consider that a voice call involves transmitting and receiving roughly 60 kilobytes of data per minute, which normally only costs you a few cents; you can see how the cost of transmitting one small packet every five seconds will not be excessive.

In contrast to 2.5G and 3G, the 4G network is a pure packet-switched system and thus ideally suited to data traffic, although of course voice calls are still supported.

Praise for 6-element Yagi TV antenna

I've recently completed the 6-element Yagi TV antenna (siliconchip.com.au/Article/10965) – exactly as per your design in the February 2018 issue (using 316 stainless steel bolts, nuts, and washers all around). I want to say that it works brilliantly!

Presently, we have a digital antenna feeding a booster and then the signal is split out to two TV sets – one via a fairly long run of coax. While the TV on the longer run has good signal strength, we sometimes get interference that causes the sound to "chirp" and the picture to break up.

With your Yagi connected and simply poked out of a window with the boom held by hand (not optimum!), about three metres below the intended mast position, I monitored the signal strength and error rate on the TV's setup page.

The signal was just as strong with this antenna, if not better than the boosted and split version. Absolutely no errors, even when I pointed it well away from the best signal direction.

I think this project should be considered a winner!

Ian Thompson,
Duncraig, WA.

Calibrating Touchscreen Altimeter without QNH information

I recently built the Touchscreen Altimeter & Weather Station by Jim Rowe (December 2017; siliconchip.com.au/Article/10898). After referring to changes in the updated online version of the article, I was able to get it working as described.

But I am having difficulty obtaining an acceptable altitude reading. Apart from the altitude variation, most readings from the unit compare well with other devices I have around, including an Arduino with a BMP280.

The local airport QNH is about 130m below where I live so that data is not a great help to me and I don't really have any easy way to get that information anyway. While I am not particularly involved with flying, I do use indicative altitude readings as part of my work.

My benchtop is located 141.5 metres above sea level (ASL), as calculated from maps and averaged GPS data. Currently, the altitude readout I get from the unit for "MSL Reference" is

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Since its introduction in February 2016, Geoff Graham's mighty Micromite BackPack has proved to be one of the most versatile, most economical and easiest-to-use displays available! Now there's the V2 BackPack – the main difference is that the V2 can be plugged straight into a computer's USB port for easy re-programming; the V1 needs a separate USB-to-serial converter.

Prices are for BackPacks only; not for the projects listed.

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a fluctuating -10 to -12 metres with an Air Pressure of 1014.7hPa (the weather is currently quite changeable here today, 7.3°C out and drizzle, while it is 19.9°C in the workshop).

I have studied the calculations as set out in the article and the software and the included notes and I understand the relationship between barometric pressure above and below the ISA of 1013.25hPa. I have also searched online aviation sites and fully comprehend QNH and QFE.

Some of the online calculators work reasonably well and this one is quite close for QNH/QFE calculations: siliconchip.com.au/link/aakd

Using data calculated, this now indicates my bench-top altitude at between 141 and 142 metres. I thought that this may be useful information for other SILICON CHIP readers who are not using the altimeter in an aircraft but you do need to know your location altitude to make it work (Google Earth can help).

I note that the original instructions for this project refer to a setting for "Ground Reference" rather than "Input QNH Reference", with the change to the software having been made after the article was published but before the software was supplied. Is the original non-QNH capable software still available? It may suit my proposed application quite well.

Warwick Guild,
Dunedin, NZ.

Response: we have located the BASIC source code for the original version of the software and it is now available for download alongside the later (QNH-enabled) firmware.

No standard colour coding for two-wire connectors

I recently purchased an Elecrow Mini Solar LiPo Charger module from the SILICON CHIP Online Shop. I am using it to build the Touchscreen Altimeter and Weather Station project (December 2017; siliconchip.com.au/Article/10898).

Shortly after powering it up, I noticed that all three of the two-wire leads supplied have the colour coding reversed when plugged into the board connectors, ie, the red wire goes to the negative terminal and the black wire goes to the positive terminal.

Despite having the connections reversed, there does not appear to be any damage to the module; with the battery connected the output is a steady 5V and the same in USB charge mode, with the LEDs lit when appropriate.

It is easy enough to fix, and change the wires around in the plugs, but I thought it would be best to let you know in case a similar problem with other modules you may have in stock.

Warwick Guild,
Dunedin, NZ.

Response: we have a warning about this in the article (at the bottom of page 30) and also on our website, where we sell the Charger module.

The problem is that there is no standard for two-wire JST cables as to which wire is red and which is black. Some of the leads that we purchase have pin 1 red and pin 2 black while others have pin 1 black and pin 2 red. And we don't know when we order them which combination we will get.

As a result, some of the cables we supply with modules have the correct colour coding (red to +) and some are reversed. You need to check the labels on the module itself and see which wires go to which pins before soldering them.

Comments on kits

I read with interest Dr Horst Poehlmann's comments about kits in the Mailbag section of the June issue (page 10, "On Kits, Hearing Aids, etc"). When Jaycar opened a store in Albury, NSW, I stopped shopping at DSE for the same seasons Dr Poehlmann mentioned – ie, their shift away from selling kits and components.

One day, many years later, I was told by the manager, that they (Jaycar) were planning to go the same way as DSE went. Meaning: fewer kits/parts and more electronic toys. Luckily, that did not happen!

On the topic of kits, I bought the Super-7 AM Radio receiver PCB from the SILICON CHIP Online Shop. I was able to get all the parts from Jaycar, bar one – the power switch. This is available from Altronics but there is no Altronics store near me and their mail order minimum is $20. The switch I need is just $1.95.

There is an Altronics stockist in Wodonga (Vic) some 120km away but they too will only process an order for a minimum of $20 worth of parts and I'm told that it could take weeks. It's very frustrating!

Another problem I had with putting together the Super-7 Radio was

the resistors. Apart from the annoying colour-coding, if you think you'd made a mistake (after triple-checking the value), it is impossible to measure the value with your DMM once it is soldered in place. Is it because it has a capacitor in series or parallel?

Also, the resistor value printed on the PCB is blocked by the body of that resistor. Am I the only one on the planet with this problem?

Regarding Dr Poehlmann's suggestion for a project for a sound-processor for the hearing impaired, I would say "bring it on"! I myself suffer from industrial deafness. My TV has all the bass removed and treble turned up to maximum but sadly I still can't hear it properly.

I use in-ear infrared headphones with all the bass cancelled out and that seems to work. If such a project goes ahead, please don't use SMDs or microcontrollers. I'm 82, after all.

Dick Polderman,
Culcairn, NSW.

Response: Gary Johnston (the owner of Jaycar) is well aware of the disaster that befell DSE after Dick Smith sold it and is unlikely to repeat those mistakes. He has mentioned in the past that he understands the importance of hobbyists and enthusiasts to his business.

We try to minimise the number of different places you need to shop to put the parts together for our designs but unfortunately, it's rare for even a very well stocked electronics shop to have absolutely everything you need. Jaycar does sell PCB-mount toggle switches but they are bulkier than we wanted for the Super-7 AM Radio.

Altronics have a good range of components so we suggest you peruse their catalog and find another $18.05 worth of parts or other gear that you may need in the near future.

If you could do it all over again, you could order $20 worth of the Super-7 parts from Altronics. For example, they have a decent range of 100mm speakers and you could also get some of the capacitors or resistors from them. Then you could pick up the balance from your local Jaycar shop.

You aren't the only person who has problems with resistors. That is why we usually suggest that you check the value of each one with a DMM before soldering it. You can measure some component values in-circuit. Series capacitors will not affect readings and parallel capacitors will normally not prevent you from getting a correct resistance reading if you wait long enough for the capacitor to finish charging.

But where you have a resistor in parallel with a diode, transistor, IC junction or another resistor, that can prevent you from reading an accurate measurement. So it's best to be sure you have selected the right value before soldering, especially on a double-sided board, where it's more difficult to de-solder components (due to the hole plating).

Placing the resistor value label under the resistor body is a compromise; it removes any ambiguity as to which resistor it refers to and it saves space on the PCB (there often isn't room to place the labels otherwise) but it does make it harder to check the values later. We always publish PCB overlay diagrams when relevant in the magazine and you can refer to that instead.

Suggestion for complete weather station project

I noticed the WiFi Water Tank Level Meter project with some weather reporting facilities included and I was thinking about it.

I was wondering whether it would be possible to design a complete weather station along the same lines. It would measure temperature, humidity, barometric pressure, wind speed, wind direction and have WiFi so that the readings could be accessed from anywhere via the internet.

The article could also include instructions for making the enclosure to comply with the requirements for accurate readings.

I'd be interested in building such a project, particularly if there was a kit available from one of the kit suppliers.

Bruce Pierson,
Dundathu, Qld.

Response: it's an interesting idea but we think it would be quite a bit of work to build a weather station from scratch. It would need to include rainfall measurements too, with the wind vane, anemometer and tipping bucket plus enclosure to build.

You may want to look on eBay as you can get a WiFi-enabled weather station for less than $200 (including delivery); building one yourself probably wouldn't cost much less than that, once you consider all the parts that would be required. SC

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How to monitor your brain waves

An Introduction to Electroencephalography (EEG)

By Jim Rowe

Elsewhere in this issue, we describe a low-cost Brainwave Monitor which you can build to measure and record brainwaves – yours, or those of someone else. But to use that device, you need to understand what an EEG is, how to use it and how to interpret the results. This article explains what an EEG is all about.

Electroencephalography or "EEG" involves monitoring the electro-neurological activity of the brain, using electrodes placed in strategic positions on the scalp.

This is not to be confused with the ECG, or electrocardiograph, which monitors the tiny electrical signals which control the heart.

But an absence of either EEG or ECG signals means you're just as dead!

The first person known to try looking for electrical activity in brains was British physician Richard Caton, who did experiments on the exposed brains of rabbits and monkeys in 1875. He published his results in the British Medical Journal in August, 1875 (siliconchip.com.au/link/aakh).

Then in 1890 Adolf Beck, a Polish physiologist, published the results of tests measuring electrical activity in the brains of rabbits and dogs – including rhythmic activity altered by light striking the animals' eyes. As with Caton's work, this was done by placing electrodes on the exposed brains of the animals. Beck is generally credited with proposing the concept of brain waves.

German physiologist and psychiatrist Hans Berger was the first to record human EEG signals in 1924 and also the first to coin the term "electroencephalogram" to describe the function of the machine he developed.

His recordings were made using electrodes placed on the subject's scalp, rather than on the surface of their exposed brain – a far less invasive scheme, making it much more suitable for use on human subjects!

Since Berger's pioneering work there has been a lot of development of EEG measurement technology and the application of EEG recordings for diagnosing various neurological and mental health problems. Nowadays, it is used for such diverse things as distinguishing between epileptic and other types of seizures and in the analysis of sleep disorders.

The American EEG Society was founded in 1947 and the first International EEG congress was held in the same year.

There are now EEG Societies in a number of countries, as well as internationally recognised techniques regarding the placement of EEG electrodes (described below).

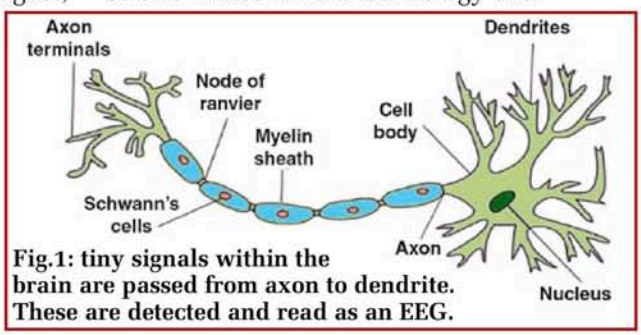


Fig.1: tiny signals within the brain are passed from axon to dendrite. These are detected and read as an EEG.

How an EEG works

Our brains are made up from billions of nerve cells or "neurons", which constantly communicate with one another by transferring ions between them via the tiny gaps or "synapses" separating them.

At one end of the synapse gap is a tentacle-like axon (a protrusion of the neuron cell) while the receiving site on the

other side of the synapse is known as a dendrite.

Since the ions are electrically charged, this means that there are small electric currents flowing all the time – especially in the outer layers of the cerebral cortex, which is the outer 'grey matter' part of the cerebrum (the large upper part of the brain).

Although these currents are quite small, a proportion of them passes through the meningeal envelope surrounding the brain and out through the bones of the skull cap and the skin of the scalp.

As a result, minute voltages corresponding to these currents can be detected using electrodes attached to the scalp, as shown in Fig.2.

Because these voltages are so tiny, a great deal of amplification is needed to sample and record them. This means that it's essential to use various techniques to cancel out "common mode" signals, such as voltages induced by nearby 50/60Hz mains wiring, which would otherwise drown out the EEG signals.

The frequencies of the EEG signals are quite low, varying between about 0.5Hz and 16Hz. This means that low-pass filtering can also be used to reject 50 or 60Hz hum.

So the basic idea of EEG is to monitor brain activity by using an array of small electrodes placed on the subject's scalp, to sense the leakage voltages present on the surface.

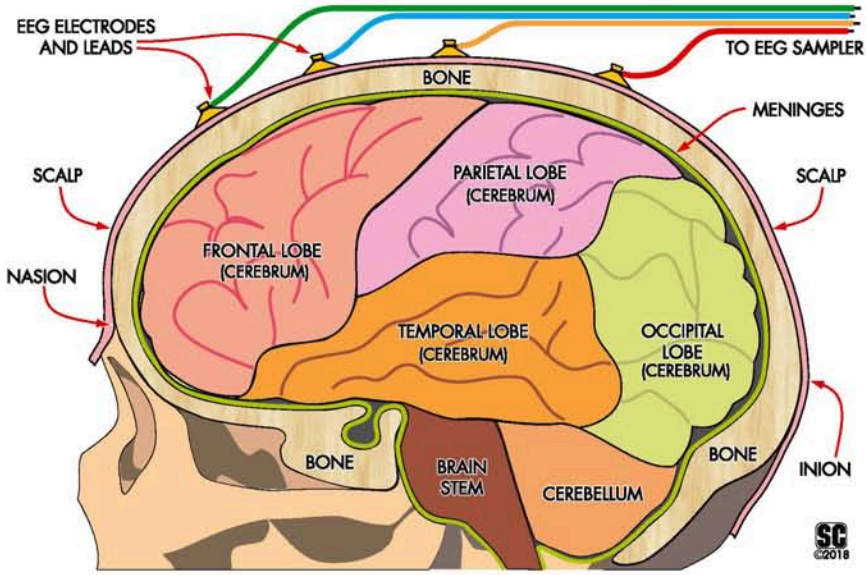


Fig.2: electrodes placed on the scalp are used to detect tiny voltages caused by currents flowing between neurons in the outer layers of the brain's cerebral cortex. A small fraction of these currents passes out through the meninges, the skull cap and the scalp.

Electrode placement

You cannot just stick the electrodes anywhere on the scalp. You must follow the standardised placement of EEG electrodes on a patient's scalp, to allow comparisons and diagnoses to be made.

The most common EEG electrode placement standard used nowadays is called the International 10-20 System, which is as follows.

Fig.3 shows two views of a stylised human head, from the side and from above. Three main reference points are shown: the "nasion", the "inion" and the "vertex".

The **nasion** is the depression directly between the eyes, just above the bridge of the nose. It's the intersection of the frontal bone and two nasal bones and is regarded for EEG purposes as the landmark for the front-centre of the skull.

The **inion** is the location of a small bump or protuberance on the outer surface of the occipital bone of the skull, which can be felt through the scalp. This point is regarded for EEG purposes as the rear centre point of the skull.

The **vertex** or top centre of the skull is basically the point halfway along the centre line of the skull, equally distant from the nasion and the inion.

This vertex is used to locate the reference ground (Cz electrode) for EEG

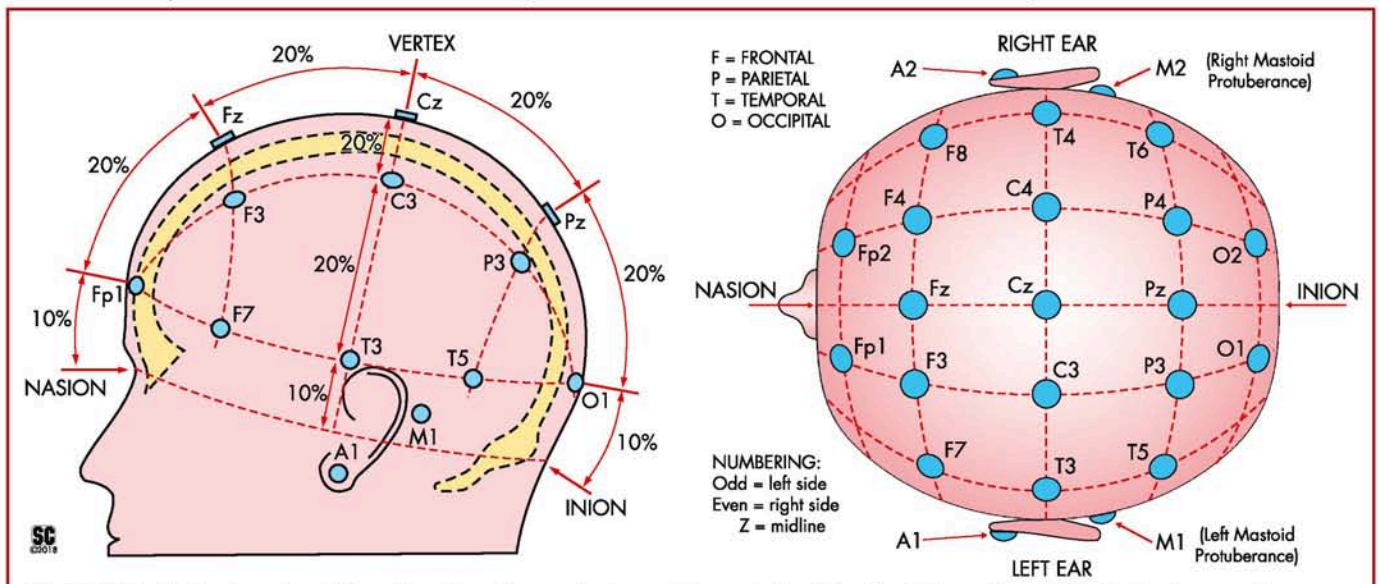


Fig.3: EEG electrodes should be placed on the scalp in positions defined by the International 10-20 System, and illustrated here.

SUGGESTED USEFUL EEG ELECTRODE COMBINATIONS		
Electrode 1	Electrode 2	Application
F4	M1	Best for slow waves (0.5 – 2.0Hz)
F3	M2	Alternative for slow waves (0.5 – 2.0Hz)
C4	M1	Best for 'spindles' (12 – 14Hz)
C3	M2	Alternative for 'spindles' (12 – 14Hz)
O2	M1	Best for Alpha rhythm (8 – 13Hz)
O1	M2	Alternative for Alpha rhythm (8 – 13Hz)
NOTE: Reference ground should always be connected to Cz electrode at top centre of skull.		

Fig.4: the combinations of EEG electrode positions which are most useful for sensing slow waves, 'spindles' and Alpha rhythms. Note that the Cz 'reference ground' electrode should always be placed at the skull's vertex.

measurements. This is used as the basis of the 10-20 EEG electrode placement grid.

The distance between the vertex and the nasion is divided into three parts, with intervals of 20%, 20% and 10% as shown, and in the same proportions for the distance between the vertex and the inion.

Similarly, the distance between the vertex and the line on each side of the head between the nasion and inion is also divided into three parts with intervals of 20%, 20% and 10% as shown in Fig.3.

These points are then used to visualise a grid, as indicated by the dashed red lines on each view. The intersections of these grid lines are used for most of the EEG electrode positions.

These are labelled using a convention where electrodes on the longitudinal centre line have the suffix "z" (as in Fz, Cz and Pz), while those on the left-hand side of the skull are given odd numbers (like F3, C3, P3, F7, T3 and T5) and those on the right-hand side are given even numbers (like F4, C4, P4 and so on). The letter prefixes given to these electrode positions correspond to the names of the brain lobes underneath their positions.

So the electrodes above the frontal lobes are given the prefix "F", those above the temporal lobes have the prefix "T", those above the parietal lobes have the prefix "P" and those above the occipital lobes have the prefix "O".

In addition to the 19 electrode positions defined by the 10-20 grid, there are four extras; two near each ear.

As shown in Fig.3, these are M1 and M2, located at the left and right mastoid protuberances (the small bumps just behind and above each external ear), and A1 and A2, located either on the lobe of each external ear or on the tragus, the small pointed skin protuberance just above and behind the lobe.

In practice, the M1 and A1 electrode positions are regarded as interchangeable, as are the M2 and A2 positions. This is because they are both very near the midpoint of the lowest grid line between the nasion and inion on each side, ie, two near each ear.

Note that for higher-resolution EEG measurements and research, many additional electrode positions are used.

Generally, these are located halfway between the grid lines shown in Fig.3. The additional electrode locations are labelled according to the Modified Combinatorial Nomenclature (MCN). But this more complex electrode array system needn't worry us here.

Which combinations are useful?

With so many electrode locations to choose from even in the 10-20 system, selecting the combinations which are likely to be the most useful can be a bit bewildering. Fortunately, people who have recorded a lot of EEGs over the years have come up with a short list of electrode combinations that have been found most useful. These are listed in Fig.4 – Suggested Electrode Combinations.

The combination of F4 and M1 (or A1) is suggested as best for capturing slow EEG waves, with the F3 and M2/A2 combination as an alternative.

Similarly, the combination of C4 and M1 is suggested as best for capturing rapid "spindle" EEG waves, with the C3 and M2 combination as an alternative.

Then for capturing the brain's relaxed "alpha rhythm", the combination of either O2 and M1 or O1 and M2 is suggested.

With all of these combinations, the EEG sampler's ground reference lead is assumed to be connected to the Cz electrode at the vertex or top of the skull. This is necessary to achieve the clearest and least noisy recordings.

So you don't need a huge number of electrodes and leads to capture the most useful EEG recordings. In fact, with only seven electrodes (including the Cz electrode), you can perform three different EEG recordings simultaneously, using an EEG Sampler with three differential input channels.

Stimulating neurons electrically

While this article is about sensing the electrical impulses generated by neurons, it is also possible to do the reverse, ie, use externally-generated electrical impulses to stimulate neurons.

We described a circuit to do just this in the project about Cranial Electrical Stimulation (CES) in the January 2011 issue (siliconchip.com.au/Article/871).

This is intended to reduce the pain from headaches and to promote relaxation.

In addition to the synapses described earlier, for communication between neurons, synapses also exist between motor neurons and muscle fibres.

The electrical impulse across the synapse causes the muscle fibre to contract and this is how the brain controls movement in the body. The injection of an electrical impulse along this path can cause the muscle to contract involuntarily.

Similarly, sensations such as heat, cold and pain cause electrical impulses which travel to neurons in the brain via synapses.

We have previously published two circuits for transient electrical nerve stimulation (TENS), which can be used for pain relief. See the August 1997 (siliconchip.com.au/Article/4848) and January 2006 (siliconchip.com.au/Article/2532) issue for details.

A warning: as you will note in the TENS articles, their output must NEVER be applied to the head, especially in the areas where EEG electrodes would go. NEVER try to connect a TENS machine to EEG electrodes (in most cases, they won't fit anyway!).

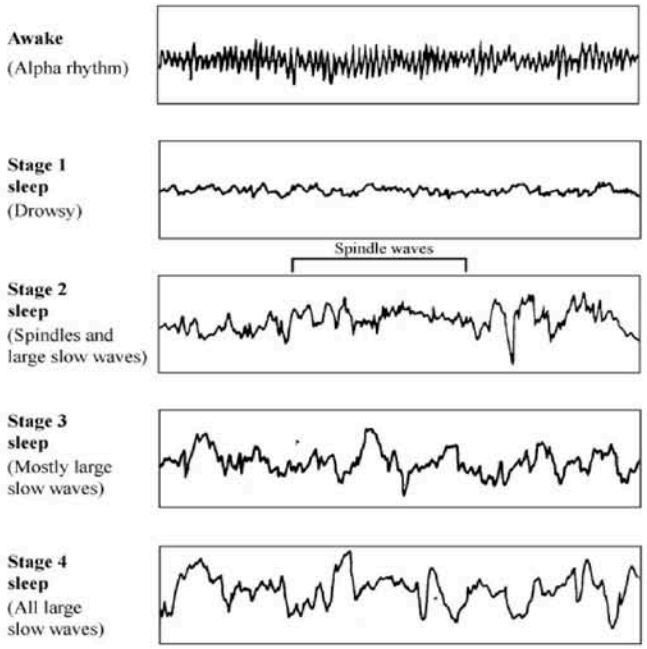


Fig.5: sample waveforms showing how EEG waves change during the various stages of relaxation and sleep.

Our Brainwave Monitor is designed for this exact task.

It's possible to switch each of the Monitor's three input channels between two alternative electrode pairs, using a small electrode switch box to be described in a future issue.

Then by using only three additional electrodes and leads (ten in all), you can capture EEGs from any of the electrode combinations shown in Fig.4, merely by selecting them using the switch box.

What to look for

So what kind of EEG waveforms can you expect when using the Brainwave Monitor?

We can't explain everything you need to know to interpret EEG waveforms in this article – that's a job for an expert. But the waveform samples shown in Fig.5 will give you an idea of the sort of waveforms you are likely to see at various stages of brain relaxation and sleep.

EEG waves are named according to their frequency range. They are Delta waves if their frequency is between 0.1Hz and 3.5Hz, Theta waves if their frequency is between 4Hz and 7.5Hz, Alpha waves for frequencies between 8 and 13Hz and Beta waves in the range 14-40Hz.

Their peak amplitude is typically between 10µV and 100µV, with Alpha waves generally less than 60µV and Beta waves usually in the range 10-20µV.

So an amplification factor of around 5,000 to 250,000 times is required for the EEG signals to be sampled by a typical analog-to-digital converter (ADC).

As you would expect, the signal amplitudes are greater if measured at the surface of the brain (1-2mV). Even this is a small fraction of the voltage of a nerve impulse, which is around 100mV.

In spite of the problems of amplifying and processing such tiny signals in a very noisy electrical environment, our Brainwave Monitor makes this a reasonably routine procedure. You can connect it to your laptop or notebook PC to view and record brainwave signals.

What a great idea for a school electronics project!

But why would *YOU* bother?

While it should be pretty obvious that an EEG in the hands of a medical professional would be extremely valuable in all sorts of clinical/diagnostic situations, the question must be asked, *"why would the average person bother reading their (or someone else's) EEG?"*

And "don't you need many years of experience to decipher EEG waveforms?"

In a professional application the answer to the latter question is undoubtedly yes – it would be folly (and probably dangerous!) for an untrained person to even attempt to analyse EEG waveforms with a view to diagnosing brain disorders.

However . . .

There are many references (on the net and elsewhere) extolling the virtues of a personal EEG in controlling and changing your own brain activity. Possibly using external simulation, with practice it appears you can "train" your brain to achieve some positive outcomes.

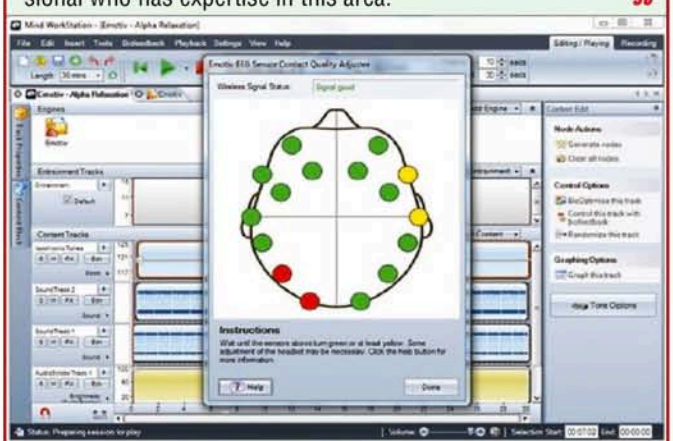
Indeed, there are several commercial organisations which offer various EEG-compatible software to enable users to experiment in this area – the example below is from the US Transparent Corporation (www.transparentcorp.com) who claim that EEG units can be tools to improve the mind through a non-invasive brain stimulation process. "Neural stimulation therapy, also commonly referred to as brainwave entrainment, uses deliberately engineered sound or light stimuli to influence the mind in beneficial ways".

Other reports we've seen suggest EEG can be used for highly stressed individuals to reduce those stress levels by recognising the types of EEG waveforms which not only reveal stress but also the waveforms which show stress reductions.

We've also seen claims that EEG analysis can help those suffering sleep disorders.

There are also reports of students who use EEG to reduce stress levels before important exams. And others which show that a general sense of wellbeing can be achieved by knowing what brainwaves show.

We're not saying that these reports are all accurate (indeed, any of them!) – the net is notorious for misinformation – but if you're interested in these, or many other "self-help" applications of the EEG, we would strongly suggest you do extensive study so that you know what you are doing. It might also be wise to discuss any possible plan of action with a health care professional who has expertise in this area. SC



Using Transparent Corp's "Emotiv EPOC or Emotiv EEG for EEG-Driven Stimulation"

by Jim Rowe

We've seen how the brain produces tiny signals which can be detected by an EEG monitor. Well, with this project you can do just that: not only monitor and display your own brainwaves (or someone else's), on a computer screen but save and print them if you wish. It's based on an Arduino Nano and connects to the computer using a standard USB cable.

There are many reasons why brainwave monitoring can be useful. As we discussed, it can help in assessing your own well-being but few people have the ability or means to do it. They can only get information on their own brainwaves if they are referred to a specialist clinic – and the most common of these would be for investigation of sleep apnea.

But you don't have to be suffering from this serious complaint to have a reason to have your brainwaves monitored and investigated (see the previous article). With this inexpensive project, you can do it yourself.

Brain waves are monitored using a number of electrodes placed on the scalp. These are readily available and not expensive. The electrodes are connected via shielded leads to the Brainwave Monitor unit, which then connects to a portable computer to display the results.

The design for this Brainwave Monitor is partly based on the circuitry of Electrocardiogram (ECG) project in the October 2015 issue of SILICON CHIP (www.siliconchip.com.au/Article/9135).

That project only needed a single channel and two electrodes to monitor electrical activity in a human heart.

This Brainwave monitor has three channels to monitor multiple electrodes. The very minute (as in tiny, not time!) signals are fed to very high gain amplifiers which are filtered and fed to a low-cost Arduino Nano microcomputer module to convert the signal readings to digital values and then sent to a PC for display and analysis.

In a little more detail, since the voltages picked up by the brain electrodes are so small, the main board has three high-gain differential input amplifiers, each of which includes a three-pole low-pass filter to reduce the devices' susceptibility to 50Hz hum radiated by mains power cables and other equipment.

The Brainwave Monitor is powered from the PC via the USB cable, so there's no need for a separate power supply. The total current drawn is less than 45mA (at 5V).

All of the Brain Wave Monitor's functions are controlled using a Windows-based GUI application written in Visual C++.

How it works

The Arduino Nano microcomputer module provides both a multi-channel analog-to-digital converter (ADC) and a USB interface.

The software loaded onto this module uses these features to continually sample the analog voltages from the front-end and sends the digitised values to your PC via the USB interface.

Fig.1 shows the block diagram which depicts the three high-gain differential amplifiers with low-pass filters which process the EEG signals to prepare them for sampling.

Capturing EEG waveforms is challenging because the voltages found on the surface of the scalp are tiny: between 10µV and 100µV peak-to-peak, depending on the positions of the electrodes on the scalp and the contact resistance.

Hence the need for amplifiers with very high gain.

To make the job harder, these voltages are completely swamped by 50Hz hum (60Hz in the USA and some other parts of the world), picked up by our bodies from the fields surrounding the AC wiring in our homes and offices

Luckily, while we are interested in the voltage differences between each pair of electrodes, the 50Hz hum picked up is virtually the same throughout the body. In other words, the 50Hz hum is a common mode signal while the EEG voltages are differential mode signals.

So by using an accurately balanced differential amplifier as the input stage of each EEG amplifier channel, we can cancel out most of the common-mode 50Hz hum while amplifying the differential EEG voltages.

The connections between the electrodes and the subject's scalp need to be good because if one connection is poor, this can upset the balance of that input amplifier and reduce the common-mode cancellation.

Another method to reduce the hum pickup is to connect a ground electrode to the top centre of the subject's scalp, in the "Cz" position (see previous article – page 14).

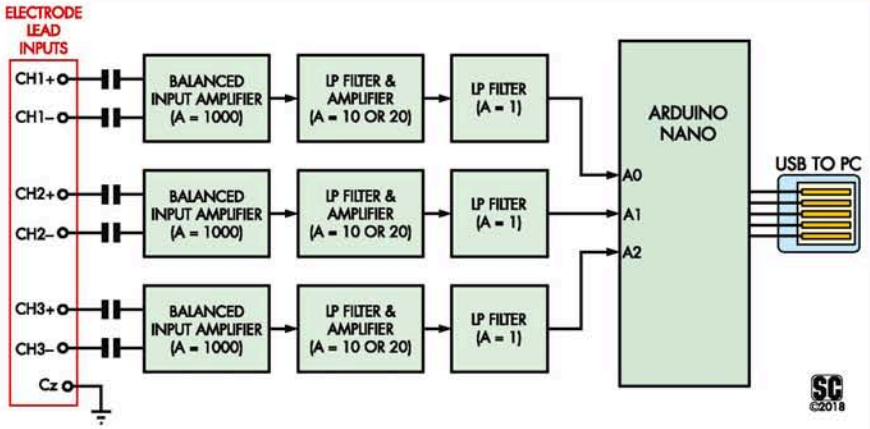


Fig.1: A simplified block diagram of our Brainwave Monitor, showing the three input amplifiers processing the tiny EEG signals and boosting them to feed the ADC inputs of the Arduino Nano.

Most of the remaining 50Hz signals are removed by low-pass filtering in the later stages of each amplifier. As a result, the output of the amplifiers provide clean amplified EEG signals, with insignificant residual 50Hz (or 60Hz) hum.

Circuit description

The full circuit of the Brainwave Monitor is shown in Fig.2. The shielded electrode leads are wired up to CON1, a DB9F connector. The six differential signals for the three channels are then fed through 1µF capacitors and series 4.7kΩ resistors to the inputs of IC1, IC3 and IC5.

These are Analog Devices AD623ARZ chips, which are instrumentation amplifiers with very high common-mode signal rejection and high gain.

The overall differential-mode gain of each AD623ARZ device is set by a resistor connected between pins 1 and 8. A value of 100Ω gives a gain of 1000 times (60dB).

To ensure that IC1, IC3 and IC5 can deliver maximum undistorted output level and so that the analog signals fed to the Arduino span its entire 0-5V ADC range, we feed 2.5V DC (ie, half the 5V supply voltage) to each amplifier's reference signal input (pin 5) from a low impedance source. This sets the DC level of the amplifier output signals to 2.5V.

The half-supply reference is provided by voltage reference REF1 (an LMV431BIMF), which sets the zero-signal output level of IC1, IC3 and IC5. The two 2.2MΩ input bias resistors for each input amplifier are returned to the same +2.5V point, providing identical biasing for the amplifier inputs.

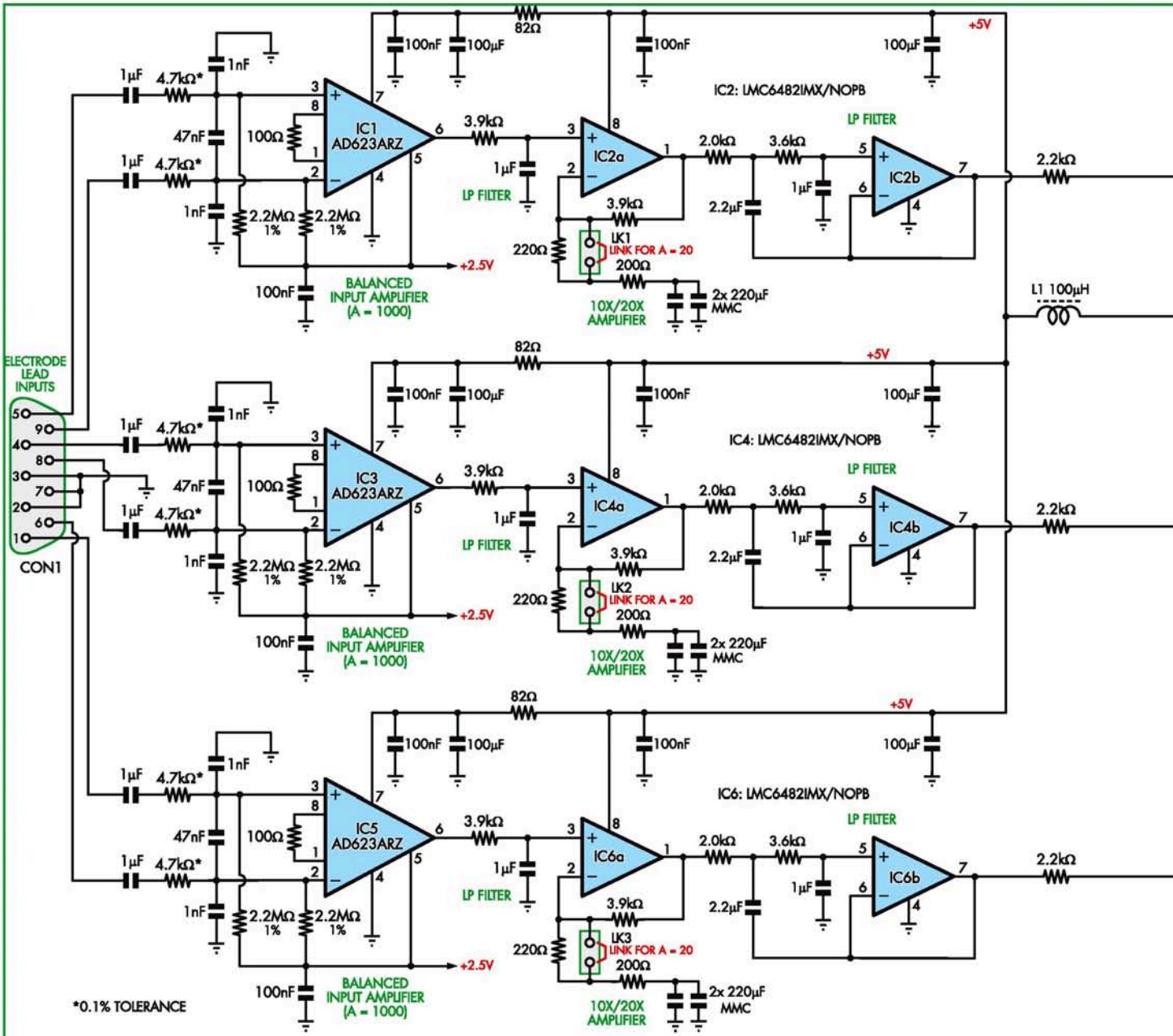
As the input amplifiers are being operated with such a high gain, we also need to prevent them from amplifying any stray RF signals which may be picked up by the electrode leads (or the subject's head and scalp).

These signals are filtered out by the 1nF bypass capacitors between each amplifier input and ground, and also the 47nF capacitors between each pair of inputs.

These capacitors form a balanced low-pass filter, in conjunction with the two 4.7kΩ input series resistors, with a -3dB point of 350Hz. Thus, the filters will be very effective at attenuating RF signals at hundreds of kilohertz and above, while having no effect on the low-frequency EEG signals.

The rest of the Brainwave Monitor's amplifier and filter circuitry is based around IC2, IC4 and IC6, all of which are LMC6482 CMOS-input dual low-power op amps. These have rail-to-rail

This project has not been designed for medical diagnosis.
Correct interpretation of EEG waveforms is a complex and skilled procedure and requires proper medical training. The Brainwave Monitor is presented here as an instructive and educational device only. If you have any concerns about the health of your brain, consult a health care professional with specialist knowledge in this area.



BRAINWAVE MONITOR
ARDUINO NANO BASED

Fig.2: the circuit is essentially two halves: on this page are the three identical high gain differential amplifiers which take their tiny inputs from the electrodes . . .

capable inputs and outputs.

The following text describes the operation of the first channel; the other two are identical.

The output from IC1 is fed to the input of IC2a via a simple RC low-pass filter formed by a series 3.9kΩ resistor and the 1µF capacitor, which gives a corner frequency of about 40Hz and an attenuation of about -4dB at 50Hz.

IC2a provides an additional fixed amplification of either 20 times or 10 times, depending on whether LK1 is present or not.

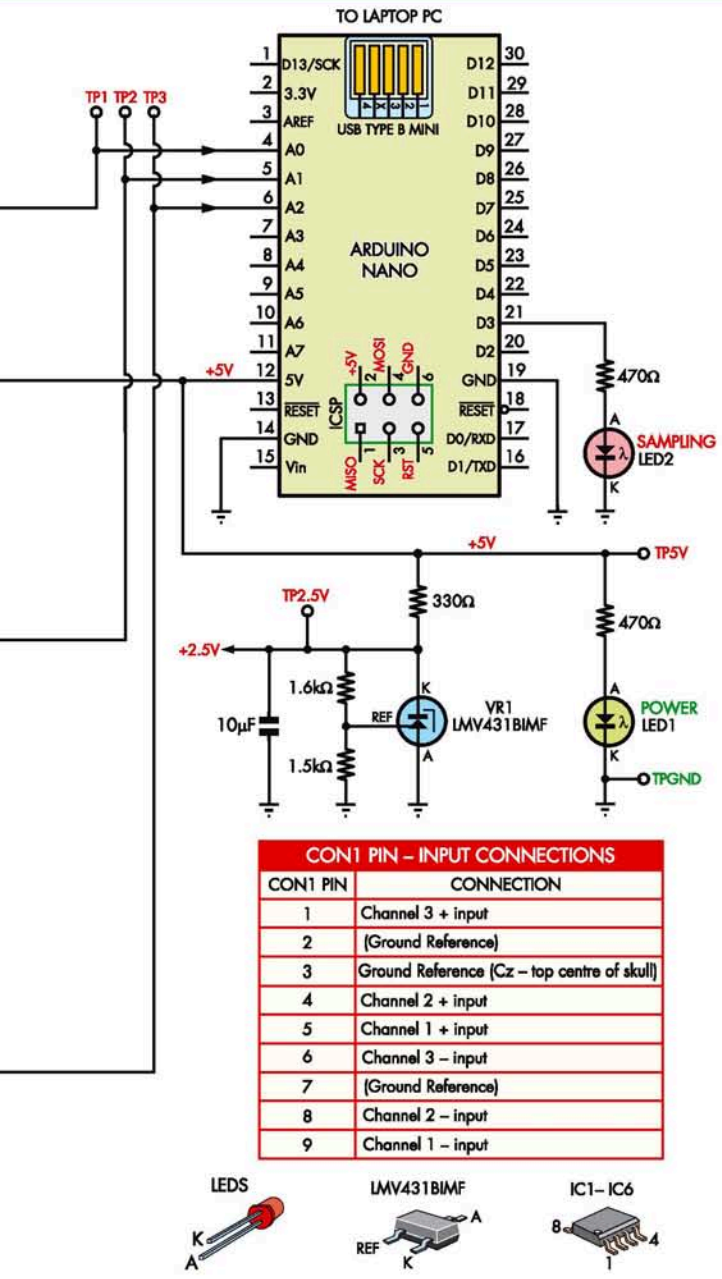
When LK1 is inserted, it shorts out the 220Ω resistor in the feedback path, altering the feedback ratio and thus increasing the stage gain to 20 times.

Either way, a parallel combination of two 220µF ceramic capacitors between the bottom of the feedback divider and ground ensure a good low-frequency response while eliminating any DC offset at the op amp output, which could otherwise lead to premature or asymmetric signal clipping.

IC2b provides additional low-pass filtering, to further reduce the 50Hz hum level. It forms a second-order Sallen-Key low-pass filter with a corner frequency of about 30Hz, giving an attenuation figure of about 15dB at 50Hz but with unity gain for the low-frequency EEG signals.

So at the output of IC2b (pin 7), we end up with relatively clean and hum-free EEG signals, amplified by either 10,000 or 20,000 times, depending on the setting of LK1.

This signal, along with the identically processed signals from the other two channels, are then fed to the A0,



CON1 PIN – INPUT CONNECTIONS	
CON1 PIN	CONNECTION
1	Channel 3 + input
2	(Ground Reference)
3	Ground Reference (Cz – top centre of skull)
4	Channel 2 + input
5	Channel 1 + input
6	Channel 3 – input
7	(Ground Reference)
8	Channel 2 – input
9	Channel 1 – input

. . . while on this page is the Arduino Nano which processes the signals from the amplifiers.

Parts list – Brainwave Monitor

1 PCB, code 25108181, 109.5 x 83.5mm
1 Diecast aluminium box, 119 x 93.5 x 34mm
1 Arduino Nano or equivalent module
1 USB cable, type A to mini-B
1 DB9F/DE9 socket, right-angle PCB-mounting (CON1) [Jaycar PS0806, Altronics P3030]
1 100µH 1.6A SMD inductor (L1) [Murata 48101SC; element14 Cat 2112367]
3 2-way SIL pin headers with jumper shunts (LK1-LK3)
7 PCB terminal pins (optional)
4 M3 x 10mm metal tapped spacers
8 M3 x 6mm panhead machine screws
4 small adhesive rubber/plastic mounting feet

Electrode components

7 EEG electrodes (see previous article)
7 26mm insulated alligator clips (three red, four black) [4 x Jaycar HM3020]
1 DB9M plug with backshell cover [Jaycar PP0800+PM0812, Altronics P3000+P3093]
1 3.6m length of figure-8 shielded stereo audio cable
1 1.2mm length of green light-duty stranded, insulated wire
1 150mm length of 4mm diameter heatshrink tubing

Semiconductors

3 AD623ARZ instrumentation amplifiers, SOIC-8 (IC1, IC3, IC5)
3 LMC6482IMX dual op amps, SOIC-8 (IC2, IC4, IC6)
1 LMV431BIMF adj. precision shunt regulator, SOT-23 (REF1)
1 3mm green LED (LED1)
1 3mm red LED (LED2)

Capacitors (all SMD ceramic except where noted)

6 220µF 6.3V X5R dielectric, 1210 size
6 100µF 6.3V X5R dielectric, 1206 size
1 10µF 25V X5R dielectric, 1210 size
3 2.2µF 25V X5R dielectric, 1206 size
6 1µF 100V MKT (leaded)
6 1µF 16V X7R dielectric, 1206 size
9 100nF 16V X7R dielectric, 1206 size
3 47nF 50V X7R dielectric, 1206 size
6 1nF 50V C0G dielectric, 1206 size

Resistors (all 0.125W 1% 1206 size SMD)

6 2.2MΩ	2 20kΩ	1 11kΩ	1 10kΩ	1 11kΩ
9 10kΩ	6 3.9kΩ	3 3.6kΩ	1 2.7kΩ	3 2.2kΩ
3 2.0kΩ	1 1.6kΩ	1 1.5kΩ	2 470Ω	1 330Ω
3 220Ω	3 200Ω	3 100Ω	3 82Ω	
6 4.70kΩ 0.1%				

A1 and A2 analog input pins of the Arduino Nano.

LED1, the power indicator, lights when the 5V supply is present, while LED2 lights when output pin D3 of the Arduino Nano goes high, which indicates that sampling is taking place.

Each IC has a 100nF bypass capacitor to ensure it has a stable supply while the supply to each instrumentation amplifier is independently filtered using an RC low-pass filter comprising an 82Ω series resistor and 100µF ceramic capacitor to ground, to minimise cross-talk between amplifiers.

These also prevent noise being coupled into the sensitive front-end amplifiers from the 5V USB supply.

The 5V USB supply for the whole circuit is also filtered by an LC low-pass filter comprising a large, high-frequency 100µH series choke (L1) and three paralleled 100µF ceramic capacitors to ground.

This LC filter is in series with the individual RC filters to each instrumentation amplifier, so they combine to provide excellent noise rejection.

Construction

All of the Brainwave Monitor circuitry, including the Arduino Nano, is mounted on a PCB measuring 109.5 x 83.5mm and coded 25108181.

Use the PCB overlay diagram shown in Fig.3 as a guide for fitting the components to the board. Many of the components on the PCB are SMDs (surface-mount devices) but there are some through-hole parts too.

Fortunately, the SMDs are quite straightforward to solder as they have fairly large and widely spaced pins.

The Arduino Nano

As explained in the circuit description, the Arduino Nano is the heart (or should that be brain?) of the Brainwave Monitor. It is effectively a miniaturised version of the familiar (and original) Arduino Uno. It's about a quarter of the size, with a PCB measuring 43 x 17.5mm. Most connections to the board made via two 15-pin SIL headers, fitted 15mm apart.

Like the Uno, this module is based on an Atmel ATmega328P microcontroller but in this case, in a 32-pin SMD package. Instead of using a second ATmega16U2 microcontroller to handle USB communication with the PC, the Nano uses either an FT232RL or a CH340G USB transceiver chip. There isn't much else on the board, apart from an AMS1117 5V low-dropout regulator, 16MHz resonator and a tiny reset pushbutton.

Power comes from the PC via the USB mini type-B connector. Like the Uno and other Arduinos, the Nano also has a 6-pin DIL pin header for in-circuit serial programming (ICSP) of the microcontroller. But normally you do not need to use this as you can program it using the USB port.

Inside the 328P chip is a reasonably fast 8-bit RISC processor with 32 registers, 32Kbytes of flash memory, 1Kbyte of EEPROM and 2Kbytes of static RAM. There are also two 8-bit timer/counters, one 16-bit timer/counter, a real-time clock and calendar with its own oscillator, six PWM channels, a 10-bit ADC with eight input channels, a programmable serial USART, a master/slave SPI serial interface, an I^2C 2-wire serial interface and an on-chip analog comparator.

When the Brainwave Monitor is working, the sequence of events is quite straightforward. Each time the software wants a set of EEG samples taken, it sends a command to the Arduino, which then uses its internal ADC to take 10-bit samples of the amplified EEG signals at its A0, A1 and A2 inputs. The sample values are then sent back to the PC, in an overall sampling cycle that takes less than 15 milliseconds.

Fit the SMD resistors first, followed by the SMD capacitors and then the six ICs. The main thing to watch with the ICs is to orientate them correctly, as shown on the overlay diagram.

For all these components, it's easiest to tack-solder one pin first, double-check the component orientation and/or value, then solder the other pin(s) and refresh the first solder joint.

If you accidentally bridge adjacent IC pins with solder, simply remove the excess using a small dob of flux paste and the application of some braided solder wick.

Using the same technique, you can now mount REF1 (in a small SOT-23 package) and the largest SMD component, L1. Then all of the leaded/through-hole parts can be added, starting with the three 2-pin headers for LK1-LK3, then the six 1µF input coupling capacitors.

Next fit CON1, making sure that all of its nine pins pass down through their mounting holes along with the two mounting lugs. Make sure that the connector's body is resting on the top of the PCB before you solder all the pins under the PCB.

Now install the LEDs with their leads straight, with the underside of each lens 12mm above the top of the PCB. Make sure they are orientated correctly, ie, with the longer (anode) lead soldered to the pad marked "A" on the PCB. Then bend the leads forward by 90°, 7mm above the top of the PCB.

Then, if you want them, add the seven optional PCB terminal pins, (used for test points).

If you've purchased a clone instead of a genuine Nano, it may be supplied with separate headers.

In this case, you will first need to solder the headers to the Nano board, ensuring that the solder joints are made on the top side of the module, with the plastic strips and long pins underneath (see photos).

Now mount the Arduino Nano on the PCB, with its USB mini-B connector facing towards the top and its two 15-pin headers passing down through the matching holes in the PCB. Make sure the plastic strips which hold each row of pins together are resting on the top of the main PCB before you solder the pins underneath.

That concludes the assembly work on the Brainwave Monitor PCB.

Installing the software

Before mounting the PCB in its case, you should verify that it's working properly. First, you will need to establish communications between the Arduino Nano module and your PC. Then you will need to load the Arduino firmware and PC software. You can then verify it's all working before going any further.

Fig.6 gives an overview of how the Brainwave Monitor works with the software installed on your computer.

If you don't already have the Arduino IDE (integrated development environment) installed on your computer, download and install it now.

The download is free and it's avail-

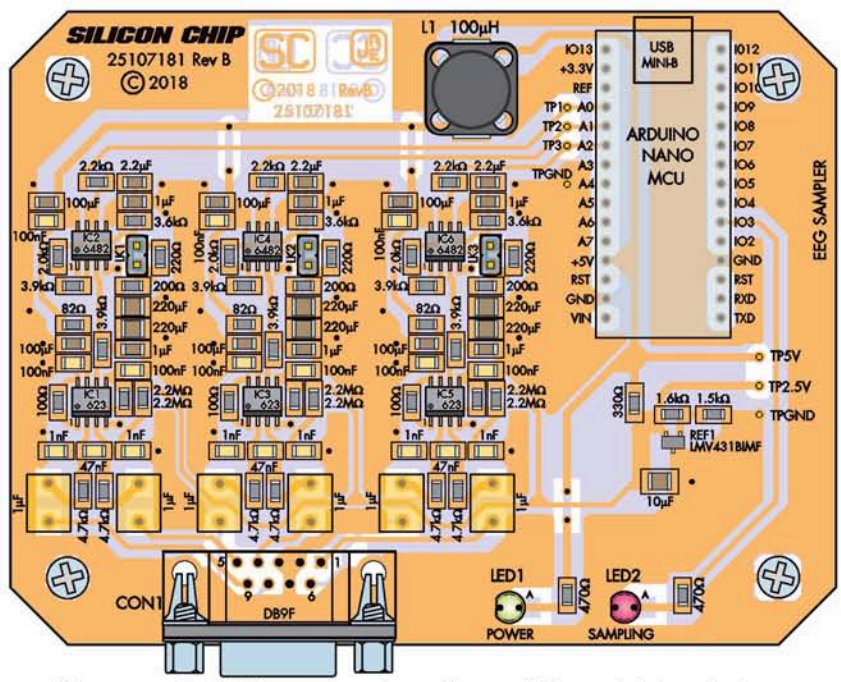


Fig.3: use this same-size PCB component overlay, and the matching photo opposite, when assembling the PCB.

able for Windows, macOS and Linux systems (but note that the main software program written for this project is for Windows only).

You can download the Arduino IDE from https://www.arduino.cc/en/Main/Software The latest version at the time of writing is 1.8.5 so we suggest you use this or a later version if possible, to ensure compatibility.

Having installed the IDE, plug the Nano board into one of your computer's USB ports (LED1 on the PCB should light up) and then start the IDE. Open the Tools → Ports menu and check the list to see if the Arduino Nano is present. If so, select it.

If it is not, that suggests that your computer may not have the appropriate USB/serial driver. Most systems will have this driver pre-installed but in some cases, it may not.

In that case, refer to the two following links for instructions on installing the FT232RL or CH341 driver, depending on which chip your Nano has been supplied with:

siliconchip.com.au/link/aakf or
siliconchip.com.au/link/aakg

Once the driver is installed, re-plug the Nano, re-launch the IDE and check that the device is now showing up in the Ports list. Select it, and ensure that the Nano is also selected in the Tools → Boards menu.

You will now need the Arduino sketch, which you can download in a package from the SILICON CHIP website (free for subscribers). The sketch file is called "sketch_for_EEG_Sampler.ino" and when the download is complete, unzip the files and open this sketch file using the Arduino IDE.

If you have set the Port and Board correctly as per the above instructions, you will just need to use the Tools → Upload menu option and the sketch should be compiled and uploaded onto the Arduino Nano. Your Brainwave Monitor is then ready to go. You just need the matching Windows software loaded on your PC.

SAFETY WARNING

To ensure complete safety, this Brainwave Monitor must *only* be used with a battery-powered laptop or notebook PC, ie, one that is NOT connected to the mains in any way. Do NOT use it with a desktop or laptop PC that is powered from 230VAC.

This precaution is necessary to eliminate the remote possibility that a fault in the power supply of a mains-powered PC could result in a high AC voltage being applied to the EEG electrodes attached to the scalp, which could have fatal consequences.

Testing

Now close the Arduino IDE. You will need to install the Windows program on your PC to test out the Brainwave Monitor.

It's also available as a download from the SILICON CHIP website and is called "SiliconChipEEGSamplerSetup.exe". Run this setup program and follow the prompts to install it on your system. When that's complete, launch the software.

Select the correct COM port (the same one that was used to upload the sketch earlier) and set the baud rate to 115,200. Start sampling and check that the software is able to connect to the Brainwave monitor and displays some traces. Of course, at this point the traces will probably just show noise. But at least you will have a pretty good indication that everything is working.

You can run your fingers along the 9-pin connector pins to check that each channel is being correctly sampled; this should induce some voltage on the inputs and cause a signal to appear, although it's likely to overload the channels, resulting in something that looks like a square wave.

Final assembly

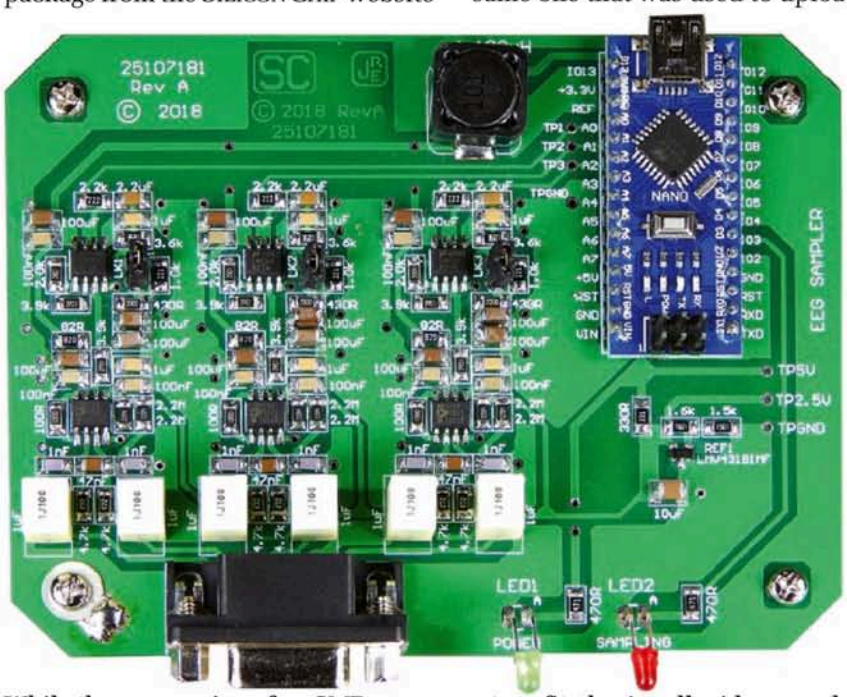
The complete PCB assembly fits inside a standard diecast aluminium box measuring 119 x 93 x 34mm. The PCB assembly mounted on the inside of the box lid with the box itself lowered down over the assembly to form a shielding enclosure; the lid then becomes the base.

Note that some of the diecast boxes we purchased recently had somehow missed out on the tapping of their mounting holes and we had to tap them by hand. So it would be a good idea to check the holes in your box before you begin final assembly.

The DB9F connector (CON1) used for the EEG electrode leads is accessed through a 31 x 17mm cross-shaped hole in the front of the box, with the two indicator LEDs protruding through a pair of 3.5mm holes to the right. The Arduino Nano's Mini-B USB socket is accessed via a 10 x 12mm rectangular hole in the rear of the box.

These holes in the case should be located and cut as accurately as possible so that the PCB assembly will fit properly. Refer to the drilling diagram, which can be downloaded as a PDF file from the SILICON CHIP website (free for subscribers). Once the box has been prepared, you're ready for the final assembly stage.

The completed PCB is attached to the inside of the box lid using four



While there are quite a few SMD components to fit, they're all wide-spaced-pin types so they shouldn't cause you any grief when soldering!

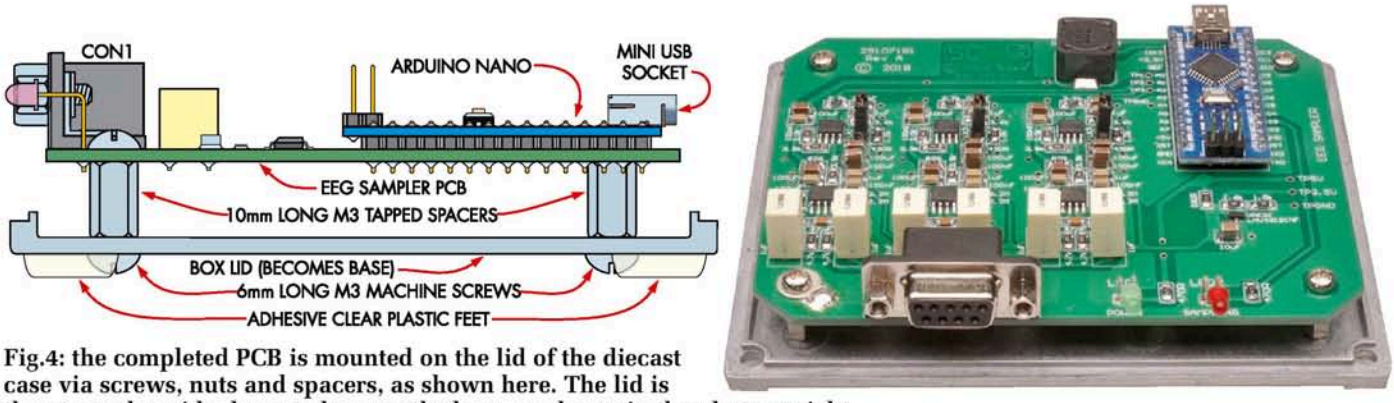


Fig.4: the completed PCB is mounted on the lid of the diecast case via screws, nuts and spacers, as shown here. The lid is then turned upside-down to become the base, as shown in the photo at right.

10mm-long M3 tapped metal spacers and eight 6mm-long M3 screws. Refer to Fig.4 for details.

Having mounted the PCB to the inside of the lid, fit the jumper shunts to LK1-LK3. This will set the gain of all three input channels to 20,000, which is the best setting to start with.

Now lower the main part of the case down over the PCB, tilting it at an angle of 20° or so at first so that CON1 and the two LEDs fit through the holes in the front of the case. You can then lower the back side down onto the lid, while at the same time moving the case slightly towards the rear. Once it's together, use the four supplied countersunk-head M4 screws to attach the lid to the case.

The final step is to apply a label to the top of the box. Like the box drilling diagram, the artwork for the dress front panel can downloaded as a PDF file from the SILICON CHIP website.

Either way, we suggest that you hot-laminate the artwork for protection against scratching and/or finger grease, and then attach it to the top of the box using double-sided adhesive tape or a thin smear of silicone sealant.

We suggest that you also fit four small adhesive rubber or plastic feet to the box lid/base, so the heads of the PCB mounting screws won't scratch any surface it's placed on.

The electrode leads

Although it's fairly easy to get hold of commercial EEG electrodes at relatively low cost, this isn't the case with electrode leads. They are available online but are generally very expensive. And most of them are not shielded and they are typically fitted with special line socket connectors for compatibility with commercial EEG machines.

So regardless of which type of electrodes you use, the best approach is to make the leads yourself.

You can do this using a 3.6m length of good quality figure-8 shielded audio cable, which you can get from Jaycar or Altronics.

Don't try to use cheap, ready-made stereo audio leads because they usually don't provide adequate shielding. They're made to a price, not a recipe!

Cut the cable into three 1.2m lengths. Remove 25mm of the plastic sheathing from one end of each cable and then unwind the exposed screening braid, twisting them together to form the earth connection wire.

Then remove about 6mm of the insulation around the inner conductors, after which you can tin the ends of both pairs of wires, ready for soldering to the pins of the DB9M plug which connects all three leads to CON1.

At the other end of each lead, remove 10mm of the outer sleeve, then cut away the screening braid wires as close as possible to the cut end of the sleeve. Then remove about 6mm of the inner insulation and tin the exposed conductors.

Separate the two halves of the figure-8 cable by about 30cm, then slip a 15-20mm length of heatshrink tubing over the two halves and solder 26mm insulated alligator clips to the exposed wires.

These small insulated alligator clips are the easiest way to make contact with typical commercial EEG electrodes, which are fitted with a small contact stud on the top.

Commercial electrode leads have a special matching clip for these studs but small alligator clips make a good substitute. Slide the pieces of heatshrink up and over the bases of the alligator clips and shrink them down.

Here's some commercial leads and attachments which we bought on the 'net – but unlike the electrodes, which are pretty cheap, commercial leads are rather pricey!

But home-made leads, like the ones we made using good ol' crocodile clips and good quality shielded figure-8 work just as well at a fraction of the price. Note the electrode labels.

And here's how it looks on completion, with the front panel glued to the "bottom" of the case – which is now the top! Ideally, the label should have a clear covering (eg, clear adhesive vinyl or even a laminate) to protect it from grubby fingers!

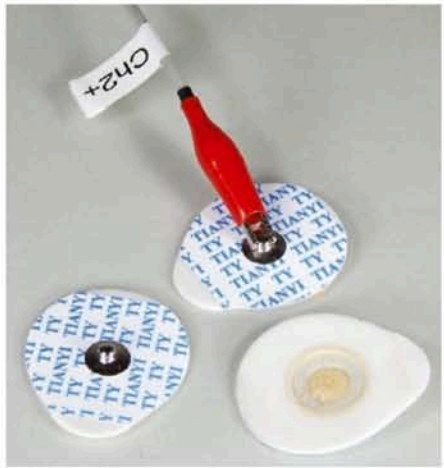


Fig.5: here's how the crocodile clips of our suggested 'DIY' leads are connected to the studs of low-cost self-adhesive electrodes. The electrode at lower right has been inverted to show its 'sticky ring' and the centre dob of conductive gel.

This will give you the six shielded leads (in three pairs) needed to connect the main electrodes to the Brainwave Monitor. But a seventh lead is needed as well – the one for the ground reference or "Cz" electrode.

This doesn't need to be shielded so you can make it using a 1.2m length of light-duty insulated hookup wire. Just strip the insulation from about 6mm at each end and tin the ends of the wire. Solder the seventh alligator clip to one end of this wire.

The final step is to solder the tinned ends of all of these leads to the appropriate pins of the DB9M plug, as shown in Fig.5.

Note that the inner conductors of each shielded lead go to pins 5, 9, 4, 8, 1 and 6, while their shield braid wires all connect to pins 2, 3 or 7, along with the wire of the ground reference lead.

Obtaining EEG electrodes

There are numerous EEG electrodes available via a number of suppliers on eBay at reasonable prices.

Many of these are cup-shaped devices about 10mm in diameter with a connection stud at the top, made from either gold-plated metal or conductive plastic.

Some of them have a flat base for contact with the scalp, while others have a double-hexagon array of tiny feet. Some typical samples are shown in the photo opposite.

Some of these electrodes are intended for wet use, with a smear of conductive gel under the cup to ensure good electrical contact with the scalp. Others are intended for dry use, relying purely on physical pressure to make contact.

Another type of EEG electrode you'll find is a smaller version of the self-adhesive electrodes intended for ECG use (ie, monitoring the electrical activity of the heart).

These have a dob of conductive gel inside a sticky ring, with a peel-off film over them both.

All you need to do with these electrodes is peel off the protective film and then apply the electrode to the right position on the subject's scalp.

All of these electrodes have the same problem, in that they have a tendency to move or fall off if simply placed on the scalp; especially the dry types.

If you search the internet, you'll find various kinds of skull caps which are designed to hold the electrodes in position.

One of the most common types is an open grid made from elastic tubing, with small plastic ties at each intersection and a larger coupling piece down each side to allow attachment of an adjustable length strap passing under the lower jaw.

It looks quite weird, but should stop the electrodes from moving. You would first fit it over the subject's head, then slip the various electrodes under the grid in the desired positions

These caps are available at fairly low cost (around $10-20 each) but

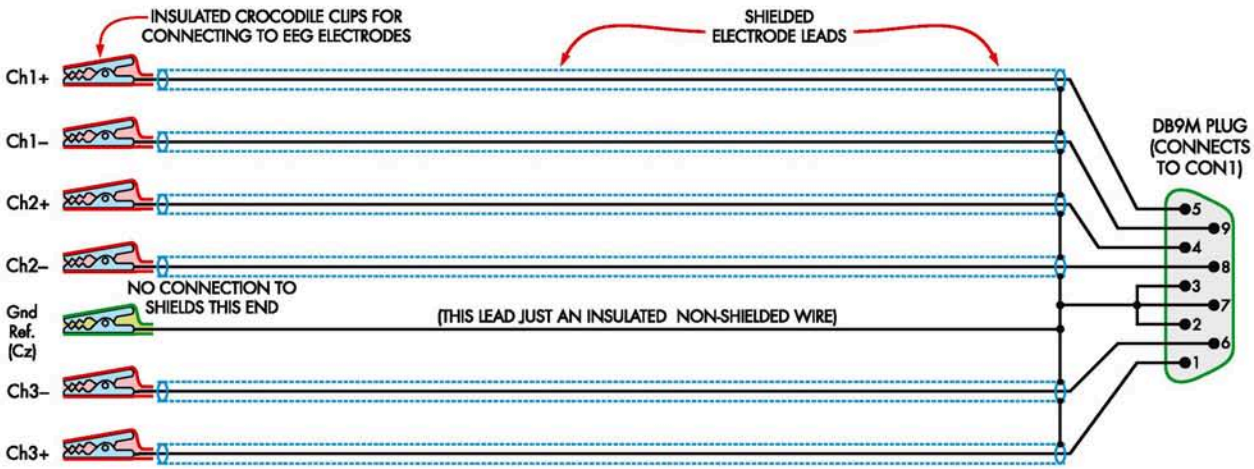


Fig.5: How to wire the seven electrode leads to the DB9M plug which connects to the Brainwave Monitor's input socket CON1. Note that apart from the Ground Reference (Cz) lead, all of the other leads should be shielded. The shields of all leads at the crocodile clip ends are left open circuit (only the internal wire is connected to the crocodile clips).

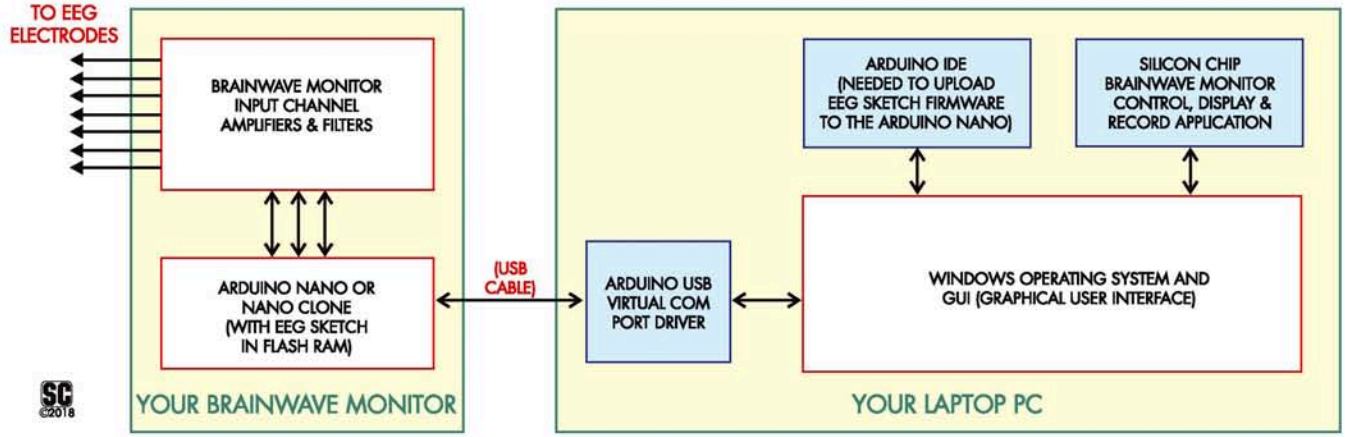


Fig.6: A block diagram showing how the 'software' side of the Brainwave Monitor works. On the left are the modules inside the Brainwave Monitor while on the right are the functions inside your laptop/notebook PC.

you also have the option of using an old-fashioned elastic rubber or plastic shower cap, which would be much cheaper.

You could mark the outside of the shower cap with the 10/20 electrode reference grid and punch holes in the appropriate positions to hold the various electrodes in place, with their connection studs protruding to allow the clips to be connected.

Taking an EEG

Apart from the gain of the input amplifiers, all other functions of the Brainwave Monitor are controlled using the software.

This is very easy to use because when you fire it up, it provides a GUI window (see screen grabs; Figs.7 and 8) which provides combo-box buttons along the top so you can set the sampling configuration: the COM port to which the sampler is connected, the Baud rate to be used (normally 115,200) for communication and the sampling time you want (5, 15, 30 or 60 seconds).

Then you start taking an EEG recording simply by clicking on the Start Sampling button.

During the sampling time, progress is shown by a progress bar along the top, plus the sample plot displays growing in the graph graticules.

As you can see there are two drop-down menus at the top, with the familiar labels "File" and "About".

The first menu gives you options for saving, reloading or printing your EEG recordings and also for closing the application when you're finished.

The second menu is merely to display a small dialog box showing the version number of the software. SC

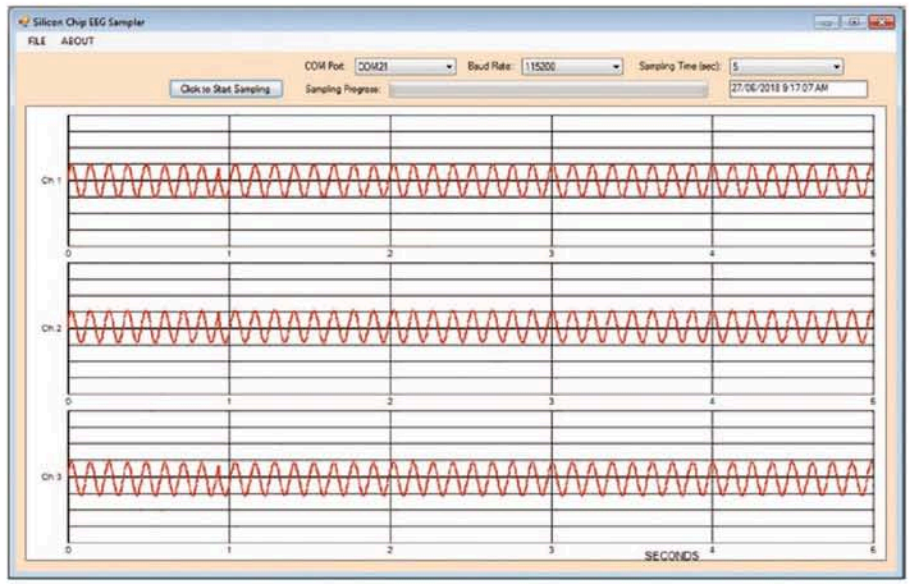


Fig.7: a screen grab taken during early testing, with an 8Hz 75uV sinewave signal from a function generator applied to all three channels.

Fig.8: another grab showing an 'ECG Waveform' from the function generator applied to all three channels, again during early testing.

Victron Connect Compatible

The *VictronConnect* app lets you get live status information and configure any Victron products which either have bluetooth built-in, or are connected to a VE.Direct Bluetooth Smart Dongle.

Can you talk to your batteries?

It might sound like sci-fi but with the Victron Energy Smart Battery Sense, you can 'talk to' your batteries using VE.Smart Networking on your mobile phone.

Connection between the Smart Battery Sense and one (or more) compatible products is via Bluetooth and can be set up easily on the *VictronConnect* app.

Once set up, you can measure battery voltage and temperature, then with a SmartSolar MPPT adjust charging parameters - all through your smartphone - to improve charge efficiency and optimise battery life.

SmartSolar MPPT

- Ultra-fast Maximum Power Point Tracking (MPPT)
- SmartSolar algorithm will always lock onto the optimum MPP for maximal energy harvest
- Improves energy harvest by up to 30% compared to PWM charge controllers & by up to 10% compared to slower MPPT controllers
- *BluetoothSmart* built in - no dongle needed
- Intelligent battery life management will ensure the battery lasts to its full extent
- Full electronic protection features

BMV-712 Smart

The BMV Smart with built-in Bluetooth is ready for the new Internet of Things (IoT) era.

With Bluetooth being implemented across more of the *Victron Energy* product range, wireless communication between products will simplify system installation and enhance performance.

Other Victron Smart Products:

Bluetooth SMART

victron energy BLUE POWER

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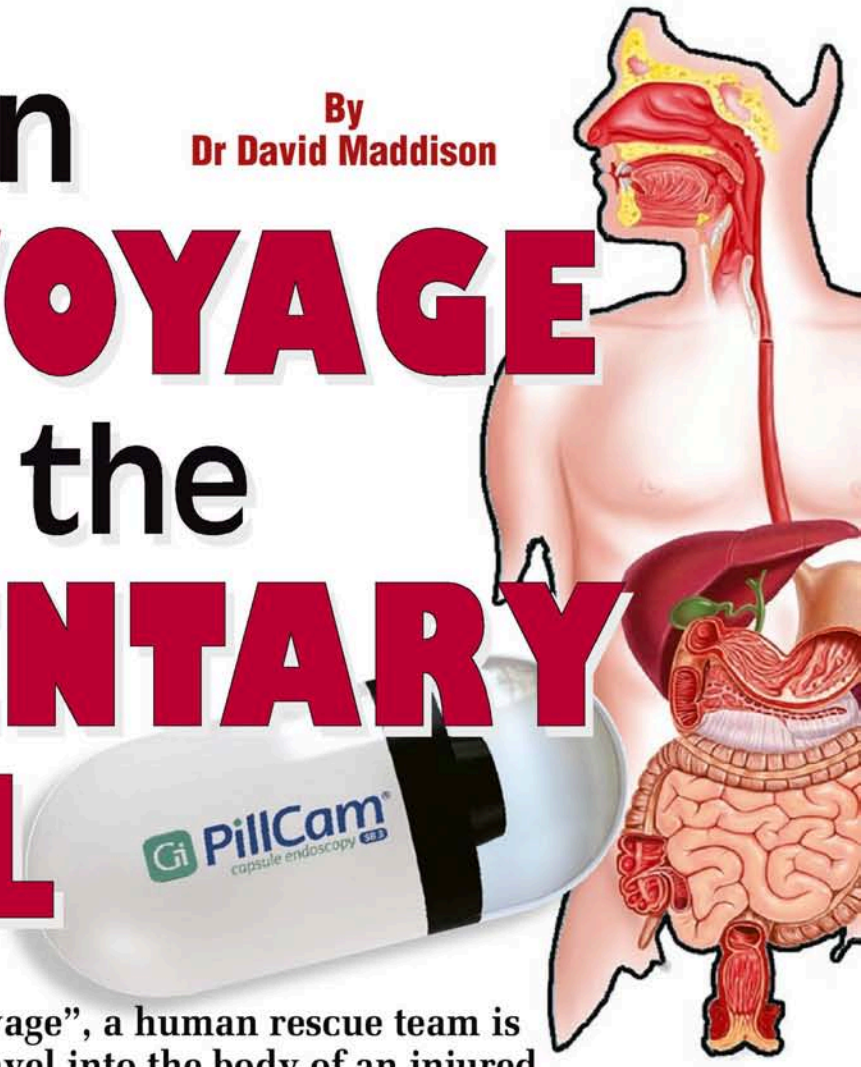
Taking an EPIC VOYAGE through the ALIMENTARY CANAL

By
Dr David Maddison



In the 1966 movie "Fantastic Voyage", a human rescue team is ultra-miniaturised in order to travel into the body of an injured scientist in order to repair damage to his damaged brain. We can't do that (yet!), but we can now swallow capsule which will make a slow trip to the farthest reaches of the alimentary canal, taking pictures all along the way.

Most older readers will be familiar with an endoscopy (from the Greek word "endo" meaning inside and "skopeein" meaning to see) – and especially a colonoscopy procedure which is an internal inspection of the gut and especially the bowel to check for the presence of cancer or pre-cancer. (If you are over 55, you should have a colonoscopy arguably every few years).

The gut (otherwise known as the alimentary canal) comprises the roughly tubular structure that starts at the mouth and ends at the anus and is associated with the absorption of nutrients from food.

When food is eaten it passes down the oesophagus to the stomach and then the small intestine, followed by the large intestine and rectum.

Modern endoscopes consist of a flexible steerable tube with a camera and light, along with various optional tools for biopsy, minor surgical procedures and sensors (eg, for pH) on the end.

Endoscopes are inserted at either end of the gut but they can only reach as far as the duodenum at one end (gastroscopy) and the large intestine and possibly a portion of the lower part of the small intestine (ileum) at the other (colonoscopy).

This means that almost all the small intestine is inaccessible. In humans, the large intestine is roughly 1.5 metres long, the distance from mouth to the duodenum is about 0.5 metres and the small intestine is six metres long. So, of the roughly eight metres of the gut, only two metres is

Some images of various organs and diseases obtained with the MiroCam camera-in-a-capsule.

accessible by conventional endoscopy.

One way to image the small intestine (and the colon) is via a "virtual endoscopy" in which data from CT and MRI scans are processed to produce images. However, the texture and colour of the organ cannot be visualised and there is a limit to the resolution. Nor is there an ability to take biopsy samples or remove polyps. But now there is "capsule endoscopy".

Lights, camera, action . . .

This swallowing a miniature "capsule" which contains a light, camera, transmitter and other electronics. About the size of a large vitamin pill, it travels through the alimentary canal via the natural action of peristalsis (the wave-like contraction of muscles that propel food and waste through the gastrointestinal tract).

This idea is not new, having first been tried in 1957 to measure pressure in the small intestine of patients with dysentery. However, the electronics required to send video data is far more complex than to send simple data such as pressure and it is only now, with miniaturised electronics, that the feat of sending video data can be achieved.

As an aside, we featured a much more recent "capsule" in the May 2018 issue of SILICON CHIP, siliconchip.com.au/Article/11060, which measures gut gases and transmits the data via radio.

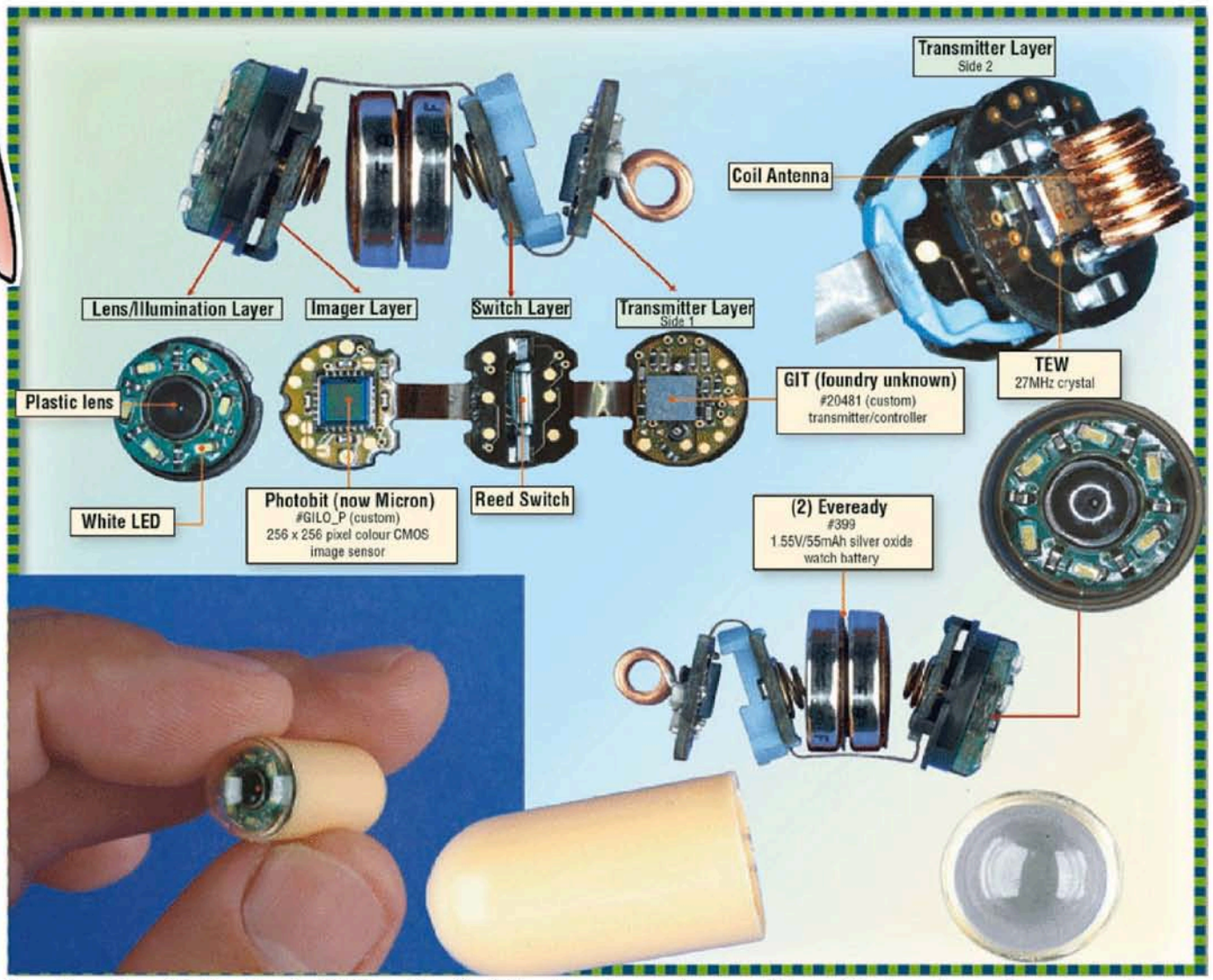
What can it diagnose?

While capsule endoscopy was originally developed to image the small intestine it is now used to image all areas of the gut. So it is now possible to diagnose conditions and diseases such as intestinal bleeding, unexplained iron anaemia, Crohn's disease, tumours in various locations, coeliac disease, gastrointestinal polyps and damage to the mucosa of the small intestine.

There are some contraindications to the technique preventing its use by patients who have conditions such as narrowing and obstructions in the gut and motility disorders.

Initial development

The first device of this nature was invented by an Israeli, Gavriel Iddan, in the 1990s. He had been thinking about



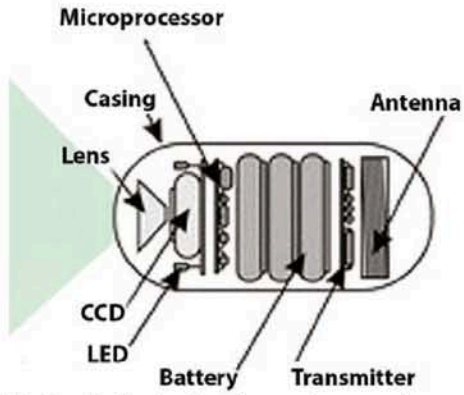
Tear down by a third party of a PillCam. One YouTuber has also made some videos of the tear down of some capsules he acquired. *"Pill camera teardown"* https://youtu.be/osAKuPGhK3I and *"Another pill-cam teardown"* https://youtu.be/bH6i3bfie_E

the problem of imaging the gastrointestinal tract since 1981, when he learned from his gastroenterologist neighbour about the problem of the inability to image the small intestine.

Iddan co-founded Given Imaging in 1998 to develop his prototype and it was released with US FDA approval and European approval in 2001.

At the time there were suitable cameras until CCD (charge coupled device) camera chips small enough to fit through the narrow confines of the small intestine became available.

But CCD chips consumed a lot of power and the batteries that could be fitted into a capsule-sized device only lasted for 10-15 minutes. It was also not practical for a physician to wait around for the capsule to pass through the body, watching images being transmitted to a monitor. Nor were available memory capacities enough to store large video images.



Parts of a typical endoscopic capsule.
Image source: Robert Koprowski, University of Silesia.

The problem was solved when Gavriel decided to have the patient wear a recording device for data that was to be transmitted from the device through the body to a receiver. This allowed the data to be reviewed by a physician at a later time. The problem of camera power consumption was also potentially solved with the invention of CMOS camera chips after he read a 1993 paper by Eric R. Fossum entitled "Active pixel sensors: are CCDs dinosaurs?"

A CMOS camera would use about one percent of the power of a CCD. Later, Eric Fossum went on to work with Given Imaging.

In 1994 Gavriel, with another Israeli, Gavriel Meron, started to look for sources of funding and started assembling a team of physicists and engineers.

His original patent, awarded in 1997, envisaged using a CCD chip and a filament lamp which consumed too much energy to be practical. It was clear then that suitable off-the-shelf, miniature, low-power-consumption cameras were not available and they would have to develop their own. One of the team, Dov Avni (whose speciality was analog video) was given the job of creating a new miniature camera and light source from scratch.

Once Dov had come up with a CMOS-based design, Gavriel Meron went to Sarnoff Corporation in the US with a view to their manufacturing the device. However, their senior researcher concluded that the thermal noise introduced to the camera operating at body temperature would be too great and would lead to an unacceptable signal-to-noise ratio.

Following this Tower Semiconductor in Israel was approached as they had then developed a means to solve the noise problem when a CMOS imaging chip operates at higher temperatures. This made it possible for Gavriel Meron to develop and produce swallowable, disposable electronic capsules. They were also the first to utilise Shuji Nakamura's invention of the white LED as a light source in a commercial optical device.

Transmitting the video

Getting a video signal from within the body was coincidentally being looked at by Paul Swain in the UK, who was transmitting video signals from small cameras from the stomachs of pigs, using microwaves. In 1997 Paul and Gavriel collaborated on the issue of wireless transmission and in 1999 Paul Swain had the honour of being the first person to swallow a capsule endoscope.

There is little information published on the specifics of how PillCam transmits data but according to a test result published by Boston Scientific in 2008, the PillCam checked for electromagnetic compatibility operated at 434MHz with a radiated power of 1μW (-30dBm).

This frequency is one of a range of different frequencies allocated by international agreement for a variety of uses and known as the ISM (industrial, scientific and medical) bands.

Given Imaging was bought by Irish company Covidien in late 2013 for US$860 million and Covidien was then purchased by US company Medtronic in 2015.

Gavriel Iddan was saddened by the sale, who thought it was "unfortunate and unnecessary".

Areas of use

Today there are three main uses for endoscopic capsules: small and large intestine and the oesophagus. For use in the small and large intestine one camera is typically (but not always) used to conserve battery life as the time of passage can be eight hours or more. A relatively modest video frame rate is satisfactory, to preserve battery life.

For use in the oesophagus two cameras can be used at opposite ends of the device, and a high frame rate is required due to the rapid passage of the capsule when swallowed and battery life is then of little relevance. In other words, as much data has to be obtained in as little time as possible.

A typical capsule endoscope system consists of the capsule itself, a system to acquire the wirelessly transmitted data or a memory system to store video data on board with certain models and software to allow a proper interpretation of the video.

A typical capsule consists of a camera with lens, LED/s for illumination, a microprocessor for system control, a battery for power, a transmitter and of course a case that is biocompatible and of a size, shape and smoothness that is least likely to become trapped.

Today there are a number of capsule endoscope systems on the market – we will take a look at some of them and their different features.

PillCam

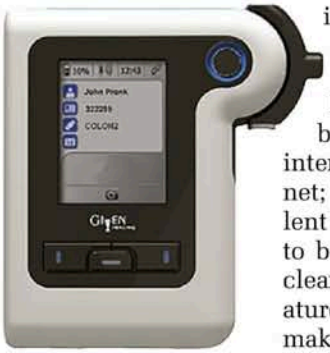
PillCam is the original capsule endoscopic capsule by Given Imaging and it is now available in several models: PillCam SB3, PillCam Colon 2 and the PillCam UGI System.

The SB3 model is designed to image the small bowel and uses adaptive frame rate technology that alters the video frame rate from between 2 and 6 fps. according to whether the capsule is moving through the bowel slowly or quickly. Camera resolution is 340 x 340. It is 26mm long

PillCam SB3 small sensor array for smaller patients such as children.

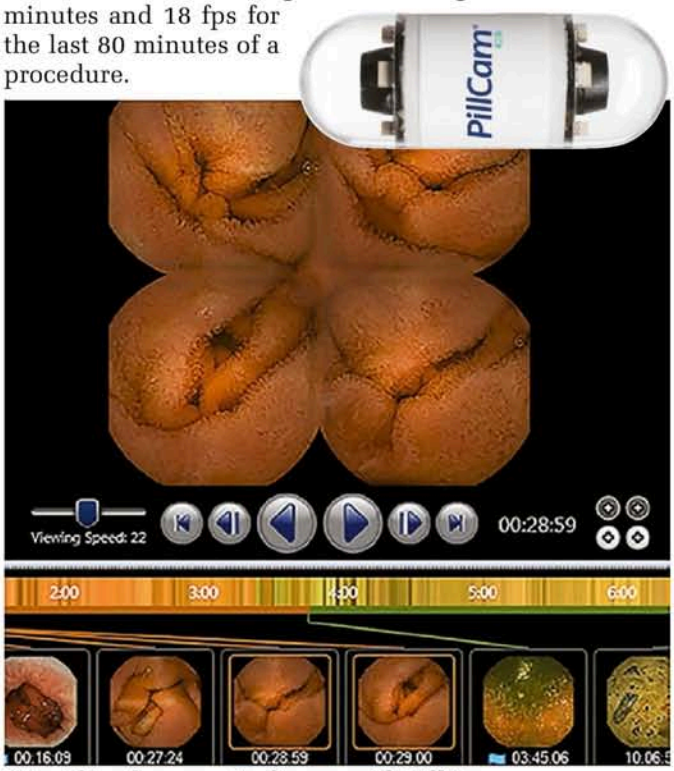
and weighs 3g.

Colon 2, designed for imaging the colon., is 32mm long and weighs 2.9g. It has two cameras, with each camera having a wide 172° angle of view for 344° total. The device has an adaptive frame rate of between 4 and 35 fps. Adaptive frame rate control is designed to prevent the transmission of unneeded data' such as when the device is moving slowly and relies on bidirectional communication between the data recorder and the device. The Colon 2 can function for up to ten hours.



PillCam Recorder 3, which is worn by the patient to record video data. It can also display a camera view in real time.

PillCam UGI, with two cameras, is intended to image the upper gastrointestinal tract (oesophagus, stomach and duodenum). The UGI operates at 35 fps for the first 10 minutes and 18 fps for the last 80 minutes of a procedure.



"Rapid" software suite for use with PillCam.

MiroCam

MiroCam is a capsule developed by Korean company IntroMedic (www.intromedic.com/eng/main/) It has dimensions of 10.8mm by 24.5mm and is available in a variety of models. Camera resolution is 320 x 320.

The device comes in three main types: the Regular model is designed to observe the small intestine and has a wide viewing angle; the Navi model is designed to be positionable in areas of interest with an external magnet; the Green model has excellent battery life and is claimed to be "eco-friendly" (it is not clear from manufacturer literature what particular attribute makes it eco-friendly).

MiroCam wireless receiver in its charging dock.

Unlike other capsule endoscopes which use radio to transmit data, the MiroCam uses electric field propagation. This is said to provide a longer battery life than radio and uses two electrodes on the capsule, the body as the transmission medium and electrodes on the skin to receive the transmitted data. A battery life of up to 11 hours is possible.

MiroCam videos: This video shows a MiroCam inside a pig, being manipulated by an external magnet *"MiroCam Navi Magnetically controlled Wireless Capsule Endoscopy Demonstration Video in porcine mod"* https://youtu.be/hoQvjP9MCQA

A corporate instructional video can be seen at *"IntroMedic's Mirocam Capsule Endoscopy System"* https://youtu.be/32N9tNmvT7w

Left: MiroCam magnetic device to manipulate location of some models of capsule. Right: MiroCam electrode belt.

Alicam

ALICAM is a capsule (made by Infiniti Medical, LLC www.alicamvet.com/) intended specifically for dogs. ALI stands for ambulatory light-based imaging. In this device the video data is stored on the device which is retrieved by the owner after the device has passed through the animal. It is then returned to the supplier where a report is produced and sent to the animal's veterinarian. Unlike

Image of duodenum observed with the OMOM capsule.

Dispose, reuse and cost?

Most capsule endoscopes are disposable and no attempt is made to retrieve them after use. except for the devices that store imagery on board, such as the CapsoCam Plus for people and the AliCam for dogs.

Since there are very high research and development costs for these products it would seem more preferable make a small profit from each unit sold than to pay a high price for a reusable device. Even in the case of the aforementioned devices that are retrieved to recover the data, they are not reused after data retrieval.

In the United States these capsules typically cost around $US500. Cheapest is the OMOM which is US$250. No pricing data was available for Australia but the Medicare item number for the capsule endoscopic procedure is 11820 with a scheduled fee of $AU2039, presumably including the cost of the device.

humans, a dog would probably try to tear off a recording harness of the type worn by people.

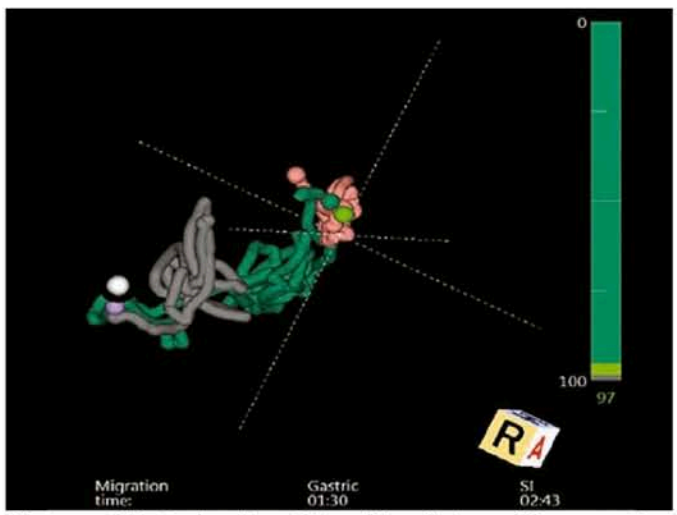
OMOM

Made by the Chinese Jinshan Science & Technology (Group) Co, Ltd (http://english.jinshangroup.com/capsuleendoscopy.html), the OMOM capsule has a battery life of ten hours and a recording system is worn on a special belt fitted around the waist while the procedure is in progress. Camera resolution is 640 x 480.

EndoCapsule EC-10

The EndoCapsule EC-10, made by Olympus, features a single camera with a 160° view, a relatively long battery life of up to 12 hours and a 3D tracking feature to estimate its approximate position by the use of radiolocation techniques. Camera resolution is 512 x 512.

The software has features to accelerate the reviewing time by not showing duplicate images. Its dimensions are 11mm x 26mm and it weighs 3.3g.



Olympus EC-10 showing 3D tracking feature. The present location and past track of the device is displayed. See videos *"ENDOCAPSULE 10 System: 3D Track Function"* **siliconchip.com.au/link/aakj and** *"Capsule Endoscopy Animation – Olympus EndoCapsule"* **siliconchip.com.au/link/aakk**

A 360° view of a patient with Crohn's disease obtained with CapsoCam Plus. Note the very high level of detail.

CapsoVision (CapsoCam Plus)

CapsoVision (www.capsovision.com/) have developed a product called CapsoCam Plus that is unique in that it stores video data in on-board memory so no external data recording harness is needed

It also generates a 360° view from four centrally-mounted cameras and appears to be identical to the AliCam for use in dogs

Unlike most other capsule devices this one has to be retrieved so the data can be downloaded. A special retrieval kit is supplied for the patient to retrieve the capsule after it is expelled. Video: *"See the 360° Difference in Capsule Endoscopy with CapsoCam Plus"* https://youtu.be/mIltjan2z6Q

Check-Cap

Check Cap Ltd (www.check-cap.com) is an Israeli company that have developed a device now in clinical trials.

The device has the same general appearance as other capsule endoscopes but uses ultra-low-dose X-rays rather than light as the imaging medium and allows for a colonoscopic procedure with no preparation apart from swallowing the capsule along with one tablespoonful of X-ray contrast agent.

The device is called C-Scan Cap and is specifically designed for colorectal cancer screening. (Some people are uncomfortable with or inadequately perform the preparation process for conventional colonoscopy)

Its position in the body is tracked by radiolocation and it uses X-rays to produce both Compton back-scattered photons and X-ray fluorescence photons. The difference between these signals provides the distance from the capsule to the colon wall and thus the information required to build a 3D map of the colon.

The capsule has an X-ray source which is collimated and rotated to produce three beams which are emitted and then subsequently detected by proprietary X-ray photon counting electronics.

Information from the capsule is collected by three patches worn on the patient's back, along with a recording device.

Video: *"C Scan"* https://youtu.be/pjBj7IIuPWg

RF System Lab. (Sayaka)

The Sayaka (http://rfsystemlab.com/en/sayaka/) is a battery-free endoscopic camera by Japanese company RF System Lab. that offers 360° imaging with a rotating central camera.

Exterior view of C-Scan Cap . . . and without its outer case.

Let the Hardware Do the Hard Work

ATmega4809 MCUs Enable Robust Embedded Control Systems

Microchip's new megaAVR® microcontrollers (MCUs) extend the capability of real-time control systems by combining intelligent hardware peripherals with the low-power performance of the AVR® core. As the first megaAVR device to include Core Independent Peripherals (CIPs), the ATmega4809 can execute tasks in hardware instead of through software. The processing power of the integrated high-speed Analog-to-Digital Converter (ADC) enables faster conversion of analog signals, resulting in faster, more deterministic system responses. These features make the new megaAVR series of an ideal companion MCU in complex microprocessor-based systems, or an excellent standalone processor in command-and-control system designs.

Key Features

- 8-bit AVR CPU core with hardware multiplier
- Up to 48 KB of Flash memory
- Up to 16-channel high-speed 10-bit ADC
- Configurable custom logic peripheral
- 6-channel peripheral event system

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The ability to acquire 360° images makes it similar to the CapsoCam Plus device which utilises four stationary cameras to do the same task.

Power is beamed to the device via microwaves and there is a microwave video transmitter on board that can capture video at up to 30fps. It has been under development for many years but does not appear to be on the market as yet. Video: *"Sayaka: Next-generation capsule endoscope"* **https://youtu.be/UHYPfcESvR0**

Bravo pH capsule

The Bravo device was designed by Given imaging (who developed the PillCam – see above) but it is not a pill camera – it is designed to measure and test acid levels (pH) arising from gastric reflux. The capsule is inserted into the oesophagus with a "conveyor" instrument whereby it is attached to the oesophageal wall via a vacuum where it remains attached for up to 96 hours, before falling off and passing through the gut to be expelled in the usual way.

Acidity is measured in the area of the lower oesophageal sphincter, the area affected by gastroesophageal reflux disease which causes heartburn. During measurement period of 96 hours the patient wears a recording device. Its dimensions are 6.0mm x 6.3mm x 26mm. *Video: "Bravo - Training Video"* **https://youtu.be/th6nR2PrWjE**

Jinshan Wireless pH capsule

Jinshan also sells a wireless pH measurement device but which appears to be similar to the Medtronic device. The device has dimensions of 6.0 x 5.5 x 26.5mm and weights 1.4g. *Video: "JINSHAN pH Capsule Feature Video"* **https://youtu.be/LDnNGugiOy8**

Data transmission rate

One source cites a typical data transmission rate from an endoscopic capsule operating at 434MHz as 267kb/s with a typical transmission distance of a number of centimetres. There are usually a number of antennas attached to the patient so the maximum transmission distance to the nearest antenna would be about half the thickness of a patient's body.

Limitations on the wireless data transmission rate can be improved with variable frame rate technology to make sure repeat images are not transmitted.

An alternative introduced with the CapsoCam Plus is to record the images on internal memory but it has the disadvantages that real-time viewing is not possible and retrieval of the capsule is necessary.

Future developments

Current capsule endoscopes are normally propelled passively by the gastrointestinal tract, although some can be manipulated with an external magnet.

Designs are being investigated that use some sort of propulsion mechanism such as arms to propel the device along or stop it at an area of interest – to perhaps take a biopsy, for example.

One example of a propulsion system successfully tested in a pig gut was developed by an Italian team in 2009 but there seems to have been no further development since then.

Another area of interest is capsule devices with chemical sensors on board such as described in the May 2018 SILICON CHIP article.

Videos and other resources

* The following video shows a capsule endoscope's view of a tape worm infestation whereby the host (both of the show and of the tape worm!) deliberately ingested tape worm eggs for the exercise. *"An investigation of Michael Mosley's tapeworms - Infested! Living with Parasites - BBC Four"* **https://youtu.be/JeDD0HdecGk**

*A video about an early "radio pill" to measure pressure in the digestive tract. *"Radio Pill (1961)"* **https://youtu.be/lNJwjt8dkoU**

*A paper from 1962 entitled *"Telemetering from within the body using a pressure-sensitive radio pill"*. This includes circuit diagrams and construction details which may be of interest. **http://gut.bmj.com/content/gutjnl/3/2/181.full.pdf**

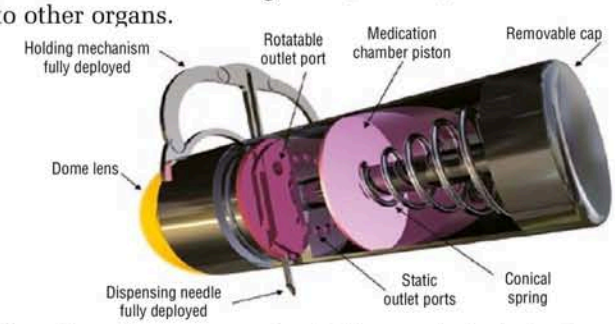
Beyond that, there is a possibility of incorporating more advanced sensors and diagnostic systems, such as on-board testing for certain biochemical markers indicative of certain conditions or diseases.

Also under development is a capsule endoscope with a drug reservoir to deliver medication to a specific area. Minor surgical procedures such as the removal of polyps are other future possibilities.

Specific location drug delivery

Another development is that of delivering drugs to specific parts of the alimentary canal.

While not *necessarily* in an endoscopic capsule – for example, see the pill currently being researched to reverse diabetes (opposite) – researchers are working on methods of delivering precise drugs to precise areas, where they will either do the most good or, indeed, not cause damage to other organs.



Capsule endoscope can also deliver up to 1ml of a drug. *Stephen Woods, Imperial College, London.*

More room without batteries

Batteries occupy a significant volume of the capsule, so their removal would allow more internal space, for additional electronics or sensor equipment. Wireless power transmission with microwaves or electromagnetic induction is currently under study.

Devices with internal memory and no external reading equipment required such as the CapsoCam Plus device could be sent to people in remote locations who cannot attend a clinic.

They could receive a diagnosis by collecting the used capsule and sending it to a clinic for analysis.

Another important area of development is smart software to reduce the reviewing time of the video by the gastroenterologist.

This might include systems to automatically identify and classify disease or other abnormal conditions.

"SURGERY IN A PILL":

A Possible Cure for Type II Diabetes?

by Ross Tester

Diabetes is said to be the biggest challenge confronting the Australian health system, with up to 1.7 million people having the disease. Of these, it is estimated that up to half a million don't realise they suffer from it.

Diabetes occurs when the body's ability to produce or respond to the hormone "insulin" is impaired, resulting in elevated levels of sugar in the blood and other (abnormal) metabolism of carbohydrates.

The result can be wild swings in the amount of blood sugar as the brain tries to adjust levels. Often it overshoots, resulting in too low a level (known as a "hypo", short for hypoglycemia) which often results in the victim collapsing. Too high a level (a hyperglycemia) can introduce a wide range of life-threatening problems.

Type 1 diabetes (10% of cases) is normally present from birth (or a very young age). Type 2 diabetes, also known as the lifestyle disease, usually manifests itself later in life and accounts for 85% of cases.

It's one of those diseases which "sneaks up on you" but uncontrolled diabetes has numerous serious health risks: eye damage (through to blindness), limb damage (4,400 amputations due to diabetes every year) along with increased risk of many other problems such as stroke, heart attack and more.

Can diabetes be cured or reversed?

While there are some exceptions, the answer is, in most cases, no. It can, however, normally be controlled to a large extent.

Most type 2 diabetics do this with a mixture of lifestyle change (a change of diet and more exercise being the chief ones) plus, in most cases, medication – either by tablet, or multiple injections of synthetic insulin each day to replace what the pancreas cannot produce.

However . . .

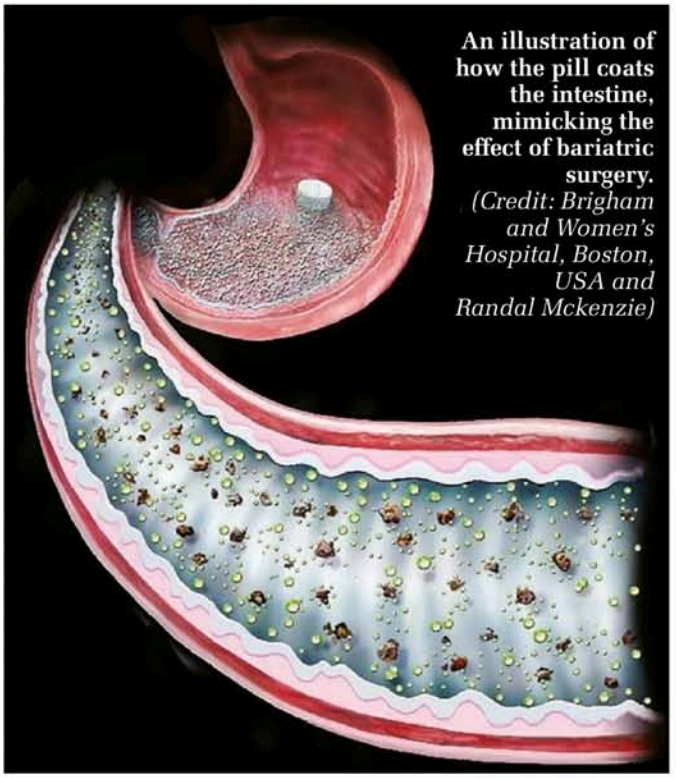
For some years, researchers have identified a connection between the apparent reversal of type 2 diabetes following bariatric surgery (commonly known as gastric-bypass surgery), where portion of the stomach is "closed off" to limit food intake.

The exact mechanism at play is still unclear but it seems to operate independently of the weight loss that comes as a consequence of the procedure.

One recent study comprising 20,000 patients found that gastric bypass surgery completely cured 84% of patients with type 2 diabetes.

Promise from a Pill!

A research team at Brigham and Women's Hospital, Boston, USA, has developed medication which can potentially mimic the effects of bariatric surgery – without the surgery!



An illustration of how the pill coats the intestine, mimicking the effect of bariatric surgery. *(Credit: Brigham and Women's Hospital, Boston, USA and Randal Mckenzie)*

It is thought that gastric bypass surgery is effective in reversing type 2 diabetes as it improves the body's glucose management, by pushing digestion processes further into the intestine. This can fundamentally alter how the body absorbs nutrients.

The team members searched for a starting material that would have just the right properties to adhere to the small intestine and then dissolve within a matter of hours. They selected a substance known as sucralfate, an FDA-approved drug that is used in the treatment of gastrointestinal ulcers. The team further engineered the substance into a novel material that can coat the lining of the intestine without requiring activation by gastric acid.

The engineered compound, referred to as LuCI (Luminal Coating of the Intestine), can be made into a dry powdered form that can be encapsulated as a pill. So far, the new substance has only been tested on rats but the results are extremely encouraging.

After a meal, blood sugar levels rise and can stay elevated over time. However, one hour after LuCI was administered to the rats, the response to glucose was lowered by 47%. The team found that this response was temporary, and after three hours, the effect essentially disappeared.

While further research is needed (including human trials), this new oral stomach-lining compound, administered simply by swallowing a pill or capsule with meals, may effectively mimic this process without the need for major bariatric surgery.

Original material from a report in "Nature" magazine, 11 June 2018. Also sourced from Brigham and Women's Hospital via EurekAlert *sc*

"Hands On" Review by Nicholas Vinen

Altium Designer 18

We're often asked what software we use to create the projects – particularly the PCBs – in SILICON CHIP. The answer is the Australian package, Altium Designer – and we've used it for around ten years. They release new versions frequently and so, during that time, many features have been added. But the latest version, Altium Designer 18, is the most radical and best update so far.

Altium Designer version numbers correspond to the year of their release, so AD18 is the 2018 version, AD17 is the 2017 version and so on.

We are currently using a mix of AD14 and AD17 (the use of AD14 comes mainly down to "inertia", ie, we were too busy to upgrade and learn the new features!).

AD18 can be installed alongside an earlier version so that you can still use the old version if necessary. Upon loading it for the first time, the differences were immediately apparent and the biggest change is that AD18 is a lot faster than AD14 or even AD17.

Altium claim that overall it's around five times faster than AD17 and for some operations, the improvement is even larger. And while some operations still take longer than I would prefer, overall it's a major improvement and I am definitely more productive (and happier!) because I don't have to wait as long for certain actions to complete.

The speed-up is most noticeable on common tasks like zooming into and out of and panning around a PCB, placing and moving tracks and so on. The 3D view is also a lot faster and looks significantly better as the simulated light source reflects off components (see Fig.1); not just the surface of the PCB, as used to be the case in the old version.

Another major change with AD18 is that they have abandoned the 32-bit version; it is 64-bit only. Since most recent desktop and laptop computers have 64-bit processors, this is not a problem however it won't work if you are running a 32-bit version of Windows. In that case, you will need to stick with AD17. Seriously, you would be better off upgrading your machine.

Along with changing to a 64-bit application, Altium have added support to take full advantage of multi-core processors. Since pretty much all desktop and laptop CPUs sold in the last decade or so have at least two cores and often four (or more), that will give significant performance benefits, especially when working on large designs.

For example, it will speed up the Design Rule Check process, which can be quite time-consuming when you make large-scale changes to a design.

User interface changes

The user interface is noticeably different. While there have been subtle UI changes in previous versions, the changes in AD18 are probably the biggest since Protel 99 gave way to Altium Designer. While these changes are significant, they

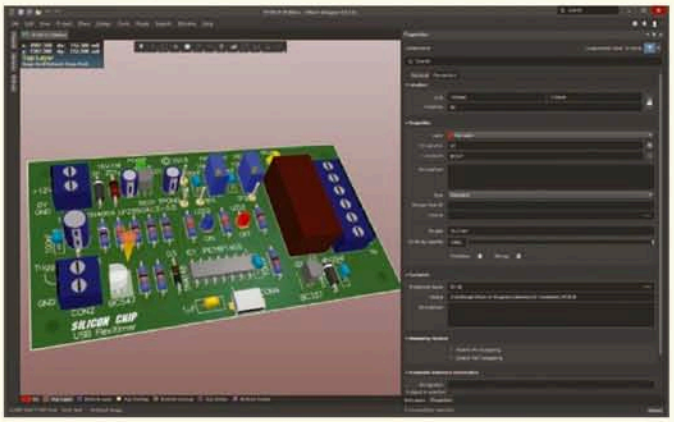


Fig.1: the 3D rendering in AD18 is much improved compared to previous versions and gives a more realistic result. It's also much faster, allowing you to zoom and change the perspective very easily. In this screen grab, the BC547 has been selected and the orange cone shows where the mouse cursor is pointing. Note the simulated light reflecting off the top of IC1 and surrounding components.

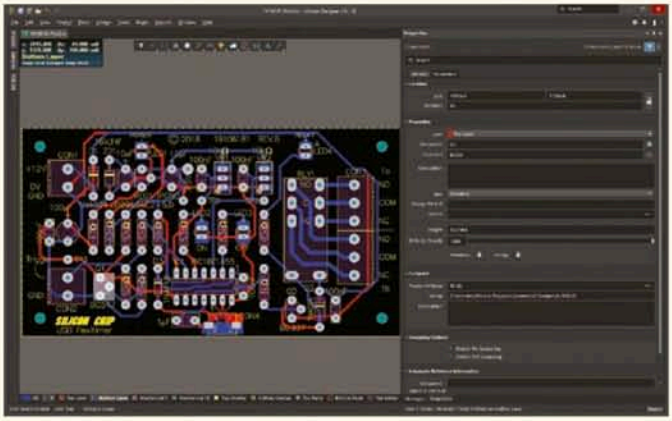


Fig.2: the normal 2D editing view of the same board shown in Fig.1. Q1 is still selected and you can see the new properties panel at the right-hand side, which allows you to easily view and change the properties of one or more components as soon as you click on them. It's also used when setting up the initial properties for new objects that are placed on the PCB or in a schematic diagram.

have taken some considerable effort to minimise the disruption on your work flow if you are already an experienced Altium user. I am certainly glad of that, given how much experience I have had using the software!

For example, in previous versions of Altium Designer, when you were placing components, tracks, vias and so on, you could press the Tab key to bring up a properties dialog. This would let you make changes such as altering the width of the track you are placing, changing the routing method or changing the particulars of the component (its name, description etc).

So when I started using AD18, I pressed Tab but was a bit confused by the fact that a dialog did not pop up as I had expected. But then I realised that the properties have now moved to a (more-or-less permanent) panel which by default appears on the right-hand side of the main editor window, although you can move it, like other dockable panels (see Fig.2).

So now, pressing Tab "freezes" the editor window (a "pause" image appears in the middle) and moves the cursor over into the Properties panel. You can then move your attention across to the side of the window and change whatever properties you need to, before "un-pausing" the editor (which can be done by pressing Enter, the same key used to close the old Properties dialog) and then resume editing.

So despite this fairly major change, because they have made the hotkeys do more or less the same job, you quickly get used to working with the new system.

I can see why they decided to make this change since the old dialog-heavy interface was rather clunky and limited. For example, you can now select multiple components and simply change their properties via the panel, as you would do with a single component.

In the past, to make multiple changes like that, you had to use the separate Inspector panel.

Selection filter and select touching/inside

Another function we often used in combination with the Inspector in earlier versions of Designer was the "Find Similar Objects" option. This is still present (see Fig.3) and it allows you to find a related group of elements in your PCB (tracks, vias, components, text, etc) and then make mass changes to them.

As noted above, the method for making those changes is different now but you can still use the Find Similar Objects menu option to actually select them if you don't want to click on each one individually and you can't just drag a box around them. This is especially important if there are hundreds of them and they aren't all in one place!

But AD18 now provides a number of other ways to select groups of objects, through both Selection Filters (Fig.4) and a much larger variety of selection modes (Fig.5). I can think of times that both of these new features would definitely have come in handy in the past.

The Selection Filter lets you choose what type of objects are selected when you drag a box around them. The options are: Components, 3D Bodies, Keepouts, Tracks, Arcs, Pads, Vias, Regions, Polygons, Fills, Text, Rooms and Other. You can choose more than one option at a time and they're all on by default.

So for example, if you want to delete all the tracks and vias in a certain area of the board so you can route them again, you can simply set the Selection Filter to Tracks and Vias only, drag a box around that area, hit delete and away you go. There were methods for doing this in earlier versions (using Find Similar Objects) but they required more steps and you could easily make a mistake.

Even more attractive are the new selection modes. Lasso select means you can draw an arbitrary shape on the PCB

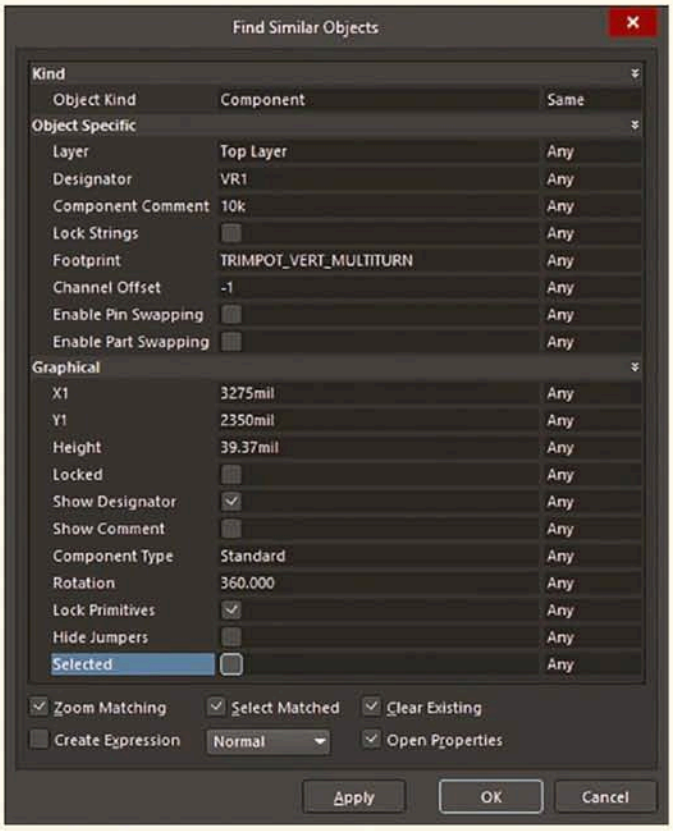


Fig.3: the Find Similar Objects dialog is a quick way to select objects on the board based on their properties. For example, you could select all objects with a particular footprint, all pads of a certain size and shape or all tracks of a certain width. Once they are selected, you can delete them or change some properties of all the matching objects with a few keystrokes or mouse clicks.

Fig.4: the new selection filter window allows you to choose what type of objects are selected when you drag an outline around them.

and select whatever is inside it. Hooray! Selecting irregular areas (which are of course quite common in PCB layouts) was a royal pain in the past. Now it's easy.

Also welcome is the ability to choose whether only those objects fully contained within the outline are selected ("select overlapped"), or whether any components which partially overlap that area ("touching rectangle") are selected. Both modes come in handy at different times. The "Outside Area" selection would be handy if you wanted to delete all but a set of components, tracks, etc.

I've used the "Select Touching Copper" option many times in the past (CTRL+H) but it's now more easily accessible through this new selection menu, along with quite a few other useful options such as being able to select a "Net", "All on Layer", "Free Objects", "All Locked" and "Off Grid Pads".

Next to this new Selection menu is a group of very useful alignment tools that lets you do things like move all component text to a specific location relative to the component (a real time saver but you do need to clean up the result), align a group of components by their centres or edges (horizontally or vertically), space components out evenly and so on.

These would have been really handy to have when I was laying out boards with rows of LEDs, resistors, relays – there are many times that having those options would have saved a significant amount of time.

The new floating toolbar at the top of the PCB editor also has a number of commonly used functions such as placing components, tracks, text, vias and so on – stuff that you use all the time is now in a more convenient location. Having said that, we tend to use keyboard shortcuts for most of these functions anyway, since that's a lot faster than moving the mouse.

Libraries

The only library supplied with AD18 is a set of "Miscellaneous Components" which has a few useful devices but if that's all you got, you would be rather disappointed.

Luckily, the reason that it only comes with the one library is that it's really easy to pull in hundreds of manufacturer-specific component libraries from the Unified Components Libraries which are hosted on Altium servers. The procedure for doing this is not obvious the first time but once you know the trick, it's really easy and the list of available components is vast.

In the "Available Libraries" dialog, you need to select the "Install from server..." option, then enter a name (that you make up yourself) in the "Library name:" field. Next, click "Add" and it will download a list of libraries from the server (see Fig.6). You can add one or more of these libraries to your local library and the components will be merged together into a single, large list.

There are so many libraries available that we can't even come close to showing them all. Fig.6 shows just some of the component libraries containing Analog Devices parts (around 5000 devices total), and they are only one of around one hundred manufacturers represented in the list.

We added the top level "Analog Devices" library to our system and Fig.7 shows the list of devices that are made available. This includes both the schematic symbols and the PCB footprints.

We haven't checked to see just how complete these libraries are but we would guess, based on past experience, that while a large percentage of current ICs and semiconductors will be available, you will still occasionally come across components that you want to use in your design for which no library element is available.

Still, we expect the Unified Components Library will save a lot of time and hassles when putting together a new design. And it should also reduce the risk that you make a mistake when creating a library element.

We noticed while browsing these components that the software sometimes paused for several seconds while downloading data. Presumably, users with a faster internet connection will notice fewer delays. But you always have the option of copying the components that you want to use to a local file, to eliminate that delay.

Simulation

There are times where we have used ECAD software to draw the same circuit up twice – once to simulate it (using SPICE), to verify that it works, then again in a different piece of software to produce a netlist which is then used in the PCB layout process.

For some time now, Altium has had the capability to run its own SPICE simulation, so you can avoid doing this work twice. To use this capability, all the components you place in your circuit need to have a model defined. This would normally be done in your libraries, however, you can add them to components after they have been placed if necessary.

Like many Altium features, getting it to work the first time is quite fiddly but once you've learned the tricks, it is generally quite easy to work with.

The first challenge was finding the library which contains the components you need for simulations, such as

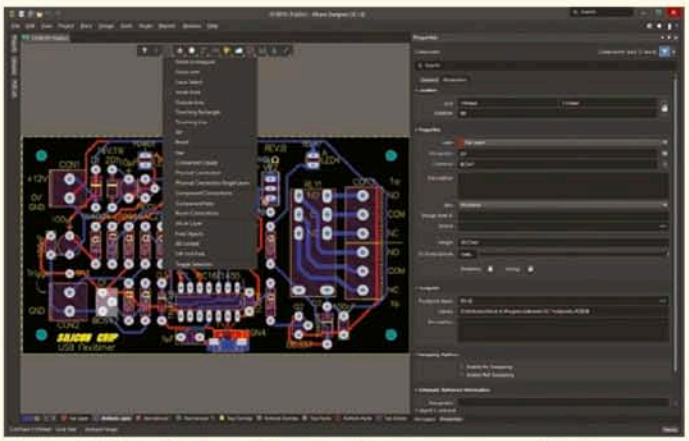


Fig.5: AD18 adds (or at least makes more accessible) many new selection modes which help you choose which objects on the board you want to move, delete, change, etc. Not shown here are the extra options available from the other icons on the new floating toolbar but they contain a number of very useful menus including those which allow you to align and arrange grids of similar objects.

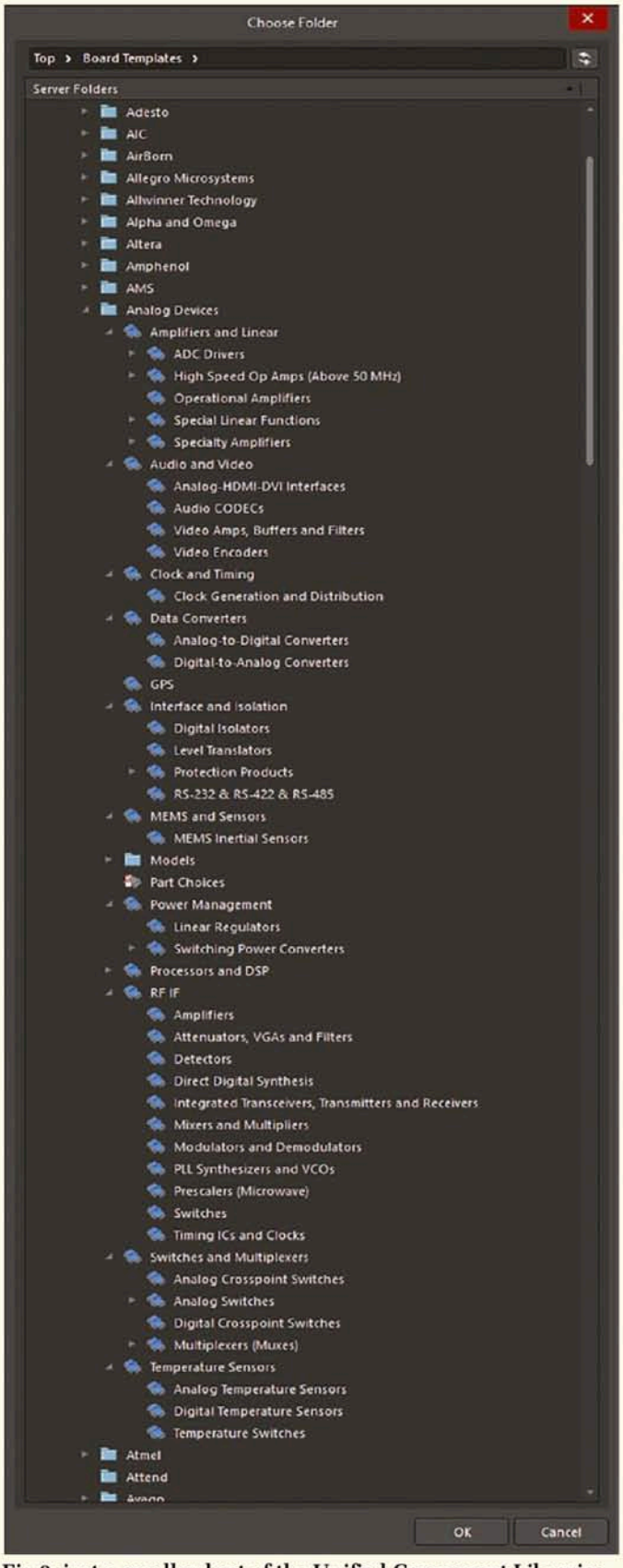


Fig.6: just a small subset of the Unified Component Libraries that can be pulled down from the Altium servers. You can select a subset of the parts available from a given manufacturer, based on their function, or simply pull in the whole lot if that suits you. You can also combine objects from multiple manufacturers into a single library on your system.

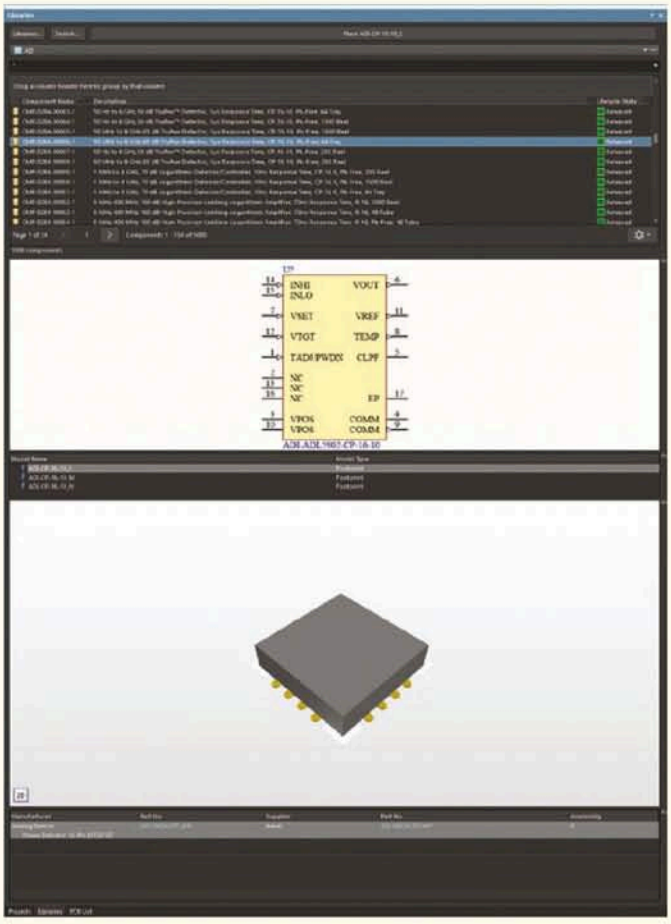


Fig.7: here we are are placing one of the 5000(!) components in just the Analog Devices library that was shown partially expanded in Fig.6. You get a preview of the schematic symbol and component footprint. In some cases, you even get supplier information, including which suppliers have it in stock and the cost. This information can then be used in the generated Bill of Materials.

voltage sources, current sources and so on. This is necessary because normally, you would simply have a connector where power is fed in but Altium doesn't know what the properties of the power source are going to be. So you need to tell it what voltages are present where, and you may also need to feed test signals into various inputs and so on.

The library is supplied with AD18 but it doesn't appear in the list of libraries by default. You have to select the "Install from file..." option and then browse to the following directory: C:\Users\Public\Documents\Altium\AD18\Library\Simulation

There, you will find five simulation libraries: Math Function, Pspice Functions, Sources (as mentioned above), Special Function and Transmission Line. Having added these, you can then add simulation elements into your schematic in the same way that you would add a normal component.

We drew up a very simple circuit to simulate, shown in Fig.8. In doing so, we discovered that the "Comment" field, where we usually put the value of a component (which appears next to the component in both the schematic and on the PCB) is not suitable for the simulation. You have to instead add a separate "Value" property to the object. That's a bit frustrating but once you know that you have to do it, it isn't much extra work.

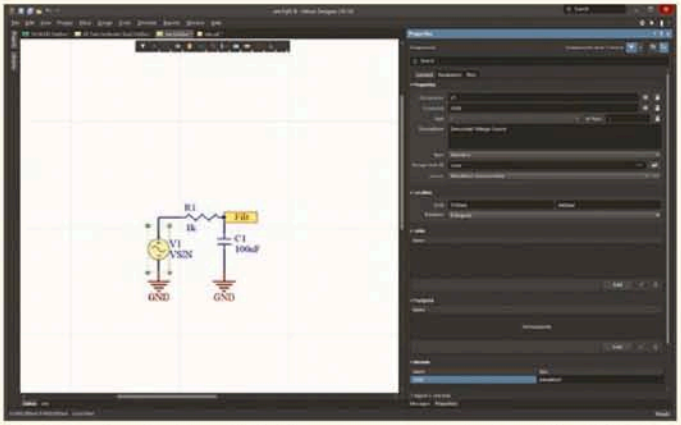


Fig.8: a simple circuit that we drew up to test out the SPICE simulation features of Altium. R1 and C1 are standard components from our library but have the SPICE Simulation model field defined. V1 is a simulation-specific component, ie, a sinewave source. If you double-click on the VSIN Simulation model shown in the lower-right corner of the window, you can set its frequency, amplitude etc.

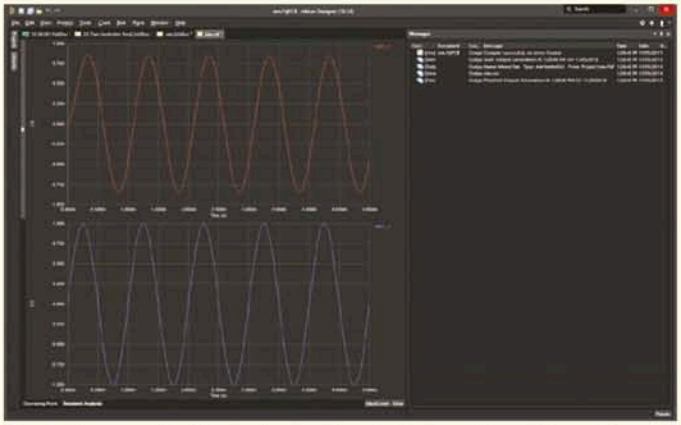


Fig.9: the result of running a simulation on the schematic shown in Fig.8. A darker background would help make the waveforms more visible but you can see that the blue trace below is the sinewave from VSIN while the red trace above is the low-pass filtered version which lags the blue trace and has a slightly lower amplitude due to the action of the RC filter.

You can then run the simulation by pressing F9 or via the Simulation menu. This menu also allows you to configure the simulation, although Altium does a good job of selecting a sensible set of default parameters.

The resulting plot is shown in Fig.9. One of the features I liked is that you can specify beforehand which signals you want to plot so that you can close the simulation and get back to working on the circuit.

Then later, when you re-run the simulation, the same plots appear. Here we are plotting the output of the sinewave source at the bottom, and the output of the low-pass filter at the top.

This shows the default colour scheme which has particularly low contrast. We would be inclined to change this if we were going to use the simulation feature seriously. There doesn't seem to be much point in having a grey background; a black one would make the plots much more visible.

Anyway, you can see that the filter output at the top "lags" the input signal below and has a lower amplitude, so the simulation is doing a good job of representing the real behaviour of such a circuit.

Multi-board designs

One of the new features added to AD18 is something we've been wanting for a while now: multi-board design capability. Previously, each project could contain multiple schematics but the parts from these schematics would automatically be deposited in a single board file.

You could in theory design multiple boards in that file but especially in larger projects, that would not be practical.

Now you use the Logical System Designer to tell Altium which schematics are associated with which modules and how those modules will be connected. You can then design separate PCBs for those modules.

You can also design the physical connections between these various boards in the Multi-board Assembly editor.

Similarly to the way that Altium handles pushing changes in a schematic through to its corresponding PCB file, when changes are made to the modules in a multi-board project, there is also a procedure to cause any changes which have been made in those modules to take effect in the overall project.

Essentially, what they have done is added a form of hierarchical design to Altium and while this is not a feature we would use all the time, it certainly would come in handy for some of our more complex projects. Any project that involves combining more than one PCB will greatly benefit from using the new System Design features.

Improved auto-routing

I'm generally not a fan of auto-routing, partly because it never really seems to do a very good job and partly because the router generally doesn't understand important parts of PCB design such as correct ground routing. However, having tried the auto-routing in AD18, I have to say that it is very good and will definitely save me a lot of time in future.

Fig.10 shows the result of auto-routing one of my designs after deleting all the existing tracks and vias. It took about 30 seconds to complete. Fig.11 shows the board that I routed by hand.

Mine is a bit neater and has, I think, a better thought-out ground network. But the auto-routed version has slightly fewer vias and overall looks pretty good. (Of course, it helps that I did arrange the components carefully.)

As well, the auto-routed version could be easily "cleaned up" to be as good (if not better) than my initial attempt. Doing that would be a lot faster than routing it from scratch. I certainly will be taking advantage of this in future!

Even if you aren't going to use auto-routing in your final design, it is worthwhile to run it in advance, just to see whether your board is even routable and where the problem areas may be. It could give you some clues about rearranging the components.

AD18 also introduces a feature known as "ActiveRoute" which is a hybrid manual/automatic routing system. It seems quite handy but you would need to spend some time familiarising yourself with its operation to take full advantage of it.

At its most basic level, you simply select one or a few

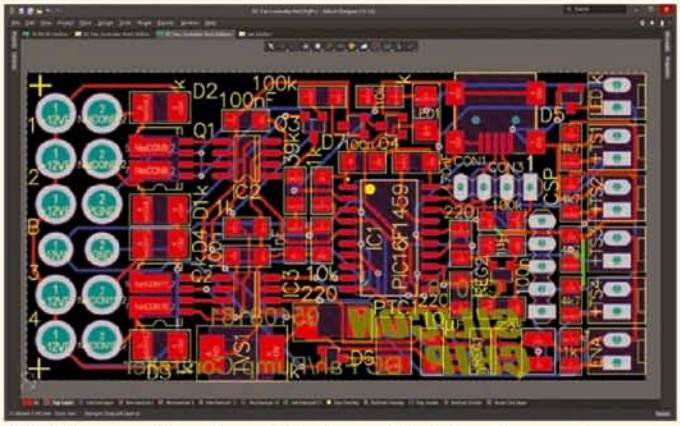


Fig.10: one of our board designs which has been auto-routed. There are a handful of design rule violations resulting in some areas being highlighted in green but these could easily be fixed manually. Overall, the result is fairly neat and logical and does not use an excessive number of vias or unduly looping tracks. Less manual tweaking would be needed if we took more time to configure the auto-router more carefully.

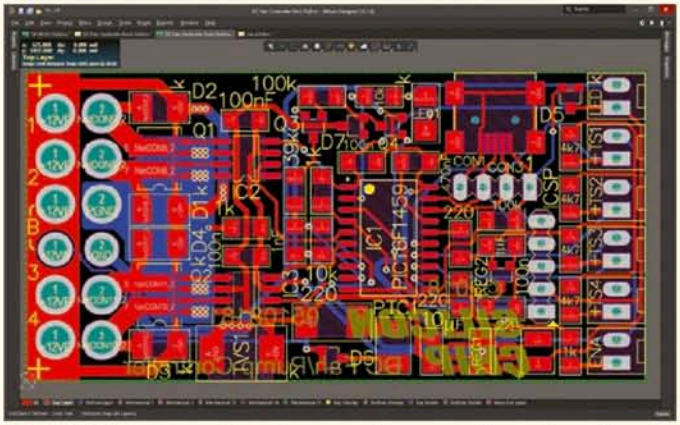


Fig.11: this is the original, manually-routed version of the board shown in Fig.10. While it is a bit neater and more carefully routed in some areas, with thicker tracks where necessary to handle higher currents, it isn't all that different from the auto-routed version. The job of manually running the tracks and polygon copper regions took many hours, compared to under a minute for the auto-router.

pads or components at a time, then press Shift+A (or select the ActiveRoute menu item) and it then automatically routes as many of the connections on the selected object as it can. In this manner, you can save yourself the time spent actually running the tracks while still deciding the order in which the routes are made.

It also appears to have the ability for you to set up rules to help guide the auto-router, to get it to do exactly what you want. This would be a real time saver on a complex board, especially one with FPGAs, CPUs and RAM. I think it's a clever idea; for example, you could let the computer automatically route the "easy" tracks to save you time but then route the critical ones by hand.

Compatibility

Generally, we didn't have any problems opening files created in earlier versions of Altium Designer in AD18. It will still open AutoTrax and Protel files; there are some problems with the imported files but that was true of previous versions as well.

One interesting quirk we noticed is how it deals with rotated text in circuit diagrams. AD14 allowed you to "flip" text but this only had the effect of changing how it was aligned (by the left or right edge); the text remained "right-side-up".

AD18 now allows you to flip text upside-down if you want to. Unfortunately, it applies this to circuits drawn up in earlier versions of the software. So text that was right-side up when we created the circuit now reads as upside-down. This is not difficult to fix, of course, but it is a bit surprising.

Major upgrades of Altium Designer are generally installed alongside existing versions rather than replacing them. For example, when I installed AD18, it left AD14 on my system and I can still go back and use that if necessary. But the installer does import the settings from the previous version so you don't need to go through and customise it all over again.

One group of settings that did not get imported, however, is the "View Configurations" which I had set up in AD14. These define the colours that are used to display the various PCB layers, how the 3D version of the board is rendered and so on. It didn't take a long time to set these up again but it would have been nice if the settings had been retained automatically. This is just something to keep in mind if you are upgrading.

I also had to re-load my custom libraries into AD18 but this is a fairly simple step and only takes a couple of minutes.

The Vault

This is a cloud-based storage system for your designs (schematics, PCBs, projects etc). It is potentially very useful when you have a team working on large and complex designs.

Since we tend to operate at a more-or-less individual level at Silicon Chip, we have not really made much use of this feature but it is available to Altium users so it is definitely worth considering.

Unlike some other ECAD packages, you are not forced to use the Vault; you can still save all the files on your local computer or network drive if you prefer to do so.

Conclusion

Altium is a huge and very complex program and few users would know how to use all of its features. But I have to say that for something so complicated, mostly it is very well thought out and not all that difficult to figure out. And once you have mastered most of the features, you will be able to produce a very large design in a reasonable amount of time and with minimal chance for errors.

One benefit to using Altium is that they have very good support. When I ran into a problem with one feature while writing this review, I sent them an email asking for help and got a response less than an hour later explaining what I was doing wrong. They also have active forums and a bug-tracking facility where you can report any problems that you encounter.

For more information about Altium Designer and purchasing a licence, contact the Australian sales office at (02) 9410 1005 or email sales.au@altium.com

SC

Super Digital SOUND EFFECTS Module

It's not *just* for model trains!

by Tim Blythman & Nicholas Vinen

Despite its miniscule size this is, by far, the most powerful sound effects module ever published in Australia . . . and we haven't seen anything else to match it – anywhere in the world! It can be loaded with dozens of sound effects or audio tracks, short or long, with a virtually unlimited playback time and advanced controls. Have a look at the features and specifications: you'll be amazed!

You won't believe that such a tiny board (just 58 x 24 x 7mm *including* the microSD card) could give such spectacular performance and versatility.

It's so tiny it can fit inside really small spaces, such as the inside of a model locomotive (hint?!).

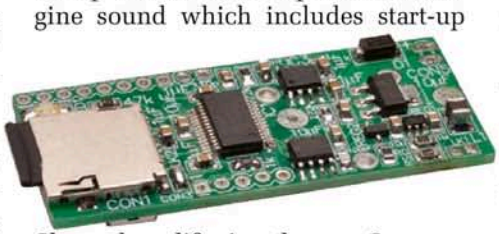
But despite its size, it is feature packed, with the ability to read and play back a large number of WAV files from an SD card, including the ability to play several simultaneously (digitally mixed together).

It has advanced sound looping support, the ability to speed up and slow down playback and the ability to select from multiple sounds for a single input, round-robin style or randomly.

And the sample length can range from a fraction of a second to many hours.

While it is obviously ideal for model railway sound effects (it can not only fit inside HO-scale [and larger] locomotives but can also be triggered by a DCC decoder).

As an example of what it could do for a model railway layout, you could set up one channel to provide an engine sound which includes start-up and shut-down sounds, when the loco starts and stops moving, and with a sound that changes in pitch with the speed of a wheel.



Shown here life size, the new Super Digital Sound Effects Module is tiny enough to fit just about anywhere . . .

You could then have other channels which overlay the engine sound with a horn, the sound of brakes squealing, an announcement or just about anything else you can think of or need. And because it operates from a very wide supply voltage (5.5-18V DC or even a pair of AAA or AA batteries) there are arguably no applications it can't handle.

But its uses are much wider than model railway layouts; in fact, it suits just about any application where sound files are required.

For instance:

- triggering a sound effect when a door

is opened or closed (a great one for Star Trek fans!),
- as part of a child's toy,
- to make a novelty greeting card,
- to make announcements in an elevator,
- as part of a vending machine,
- as an audio guide or to play sounds for museum exhibits.

The possibilities are practically limitless. We're sure there's another two or fifty rolling around in your head right now!

It will, without any add-ons, directly drive an external 8Ω speaker with its inbuilt 1.2W audio amplifier. And the sound is great!

If a speaker is too thick for any particular application, the Super Sound Effects Module can drive a piezo transducer (although, of course, the Super Sound Effects Module sound quality will not be anywhere near as good). The sounds can be triggered by switches, relays or the outputs of a microcontroller.

Compare this to a commercial-available sound effects module for a model locomotive. These typically cost over $100 and include engine sounds, horn or whistle sounds, brake sounds and others depending on the model. And they're most unlikely to have the versatility or features this module offers!

Check out these features & specifications!

- 16-bit digital-to-analog converter with 47kHz sampling rate
- Onboard 1.2W audio amplifier capable of directly driving an 8-ohm speaker
- MicroSD card slot for sound storage (some built-in sounds provided)
- Four-channel audio mixing
- Multiple sound looping options including "attack-sustain-release" mode
- Seven digital trigger inputs, triggered on a low or high level
- Each input can trigger one or many sounds (round-robin or randomly selected)
- Variable playback speed option, based on an analog voltage or pulse rate
- Plays 8-bit or 16-bit WAV files with sampling rates of 1-64kHz
- Supports mono or stereo PCM (uncompressed) files; stereo files are down-mixed to mono
- Two supply options: 2.0-3.6V battery or 5.5-18V DC input
- Very low idle current (<10µA when battery powered, <1mA from DC input)
- Typical power consumption while operation: ~40mA (depends on volume, speaker type etc)
- Typical start-up delay: <0.5s from sleep mode, <0.1s from idle mode
- Based on a low-power PIC32 running at 24MHz
- Onboard error/activity LED
- Configured via text file on microSD card

How it works

The basic circuit arrangement is shown in the block diagram, Fig.1. The Super Sound Effects Module is based on PIC32 microcontroller IC1, which reads ordinary WAV files from the microSD card and plays them back when triggered via one of its digital inputs.

Once the audio data has been read off the SD card and processed, it is fed to I²S-input digital-to-analog converter (DAC) IC2 and then to 1.2W audio amplifier chip IC3, which can drive a small (or large) speaker or a piezo transducer.

There are two power supply options shown in Fig.1, one for a nominally 3V battery and one for a 5.5-18V DC supply; there will be more details on these options later.

The Super Sound Effects Module is not just limited to simply playing one of seven sounds.

By means of a simple text-based configuration file that is saved on the card, the operation of each of the seven trigger inputs can be customised to play back one of several sounds or a series of sounds with separate volume and mode configurations for each input.

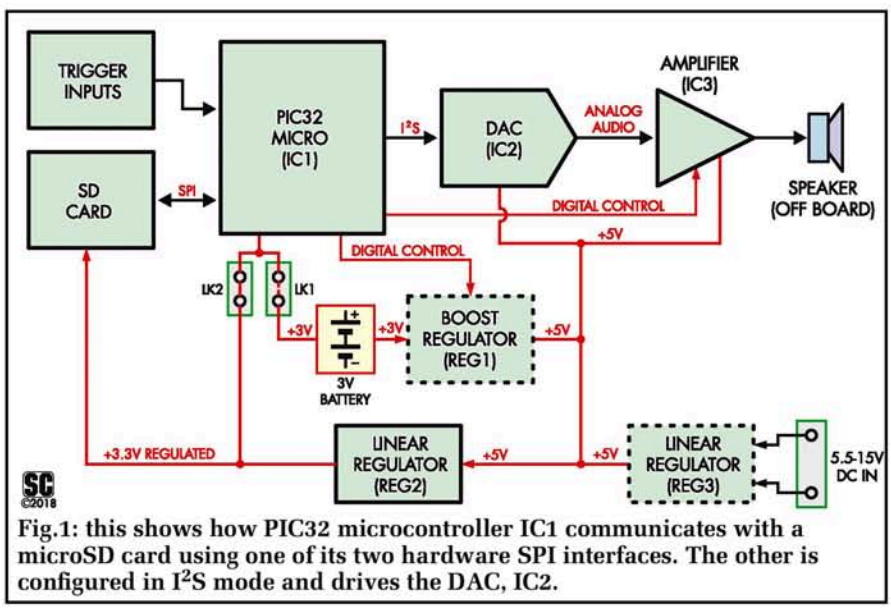


Fig.1: this shows how PIC32 microcontroller IC1 communicates with a microSD card using one of its two hardware SPI interfaces. The other is configured in I²S mode and drives the DAC, IC2.

While the sounds themselves are important, the way they are played back and mixed adds to the effect. This module has eight different playback styles that can be configured, incorporating multiple sounds for each input.

For example, a horn or whistle sound typically rises in volume, maintains a level, then fades away slowly. One of the inputs on the Super Sound Effects Module can be set up to provide this effect. For example, we can create three separate sound files: one for the rising part, one for the steady part, and one for the fading part.

When the appropriate input is pulled low, the rising level sound plays. While the input remains low, the steady sound is repeated as often as necessary and finally, the fading sound is played when the input is released.

This mode is called "ASR",

short for Attack, Sustain, Release, which describes the three phases of the overall sound effect. This style also suits generating sound effects for equipment such as compressors and dynamic brakes, which all have a characteristic ramp-up, hold and fade-away sequence.

Engine sounds are usually heard continuously, and there is an option to loop a sound as long as an input is triggered, or to alternate this with another sound that loops while the input is not triggered. There is also an option for a sound to play once when triggered, which is perfect for announcements and other one-off effects such as coupler clash or guard's whistle.

There are two more options, similar to the loop and single modes mentioned above. They more or less work in the same fashion, but if the input is released during playback, the sound stops immediately.

If one sound is triggered while another is still playing, normally they will be mixed together so that you hear them simultaneously. But this can lead to volume overload and distortion.

So each trigger input can specify a playback volume for the associated sounds, adjusted over a range of 256 steps. This allows the right balance of sounds to be set up. There is also a master volume setting which affects all sounds.

Since the unit is configured through a file on the SD card, that lets you easily combine the many available options to suit your particular application, whatever it might be.

For example, a single WAV file running in "cropped single" mode is ideal for a custom birthday card powered by a battery, as the sound will only play

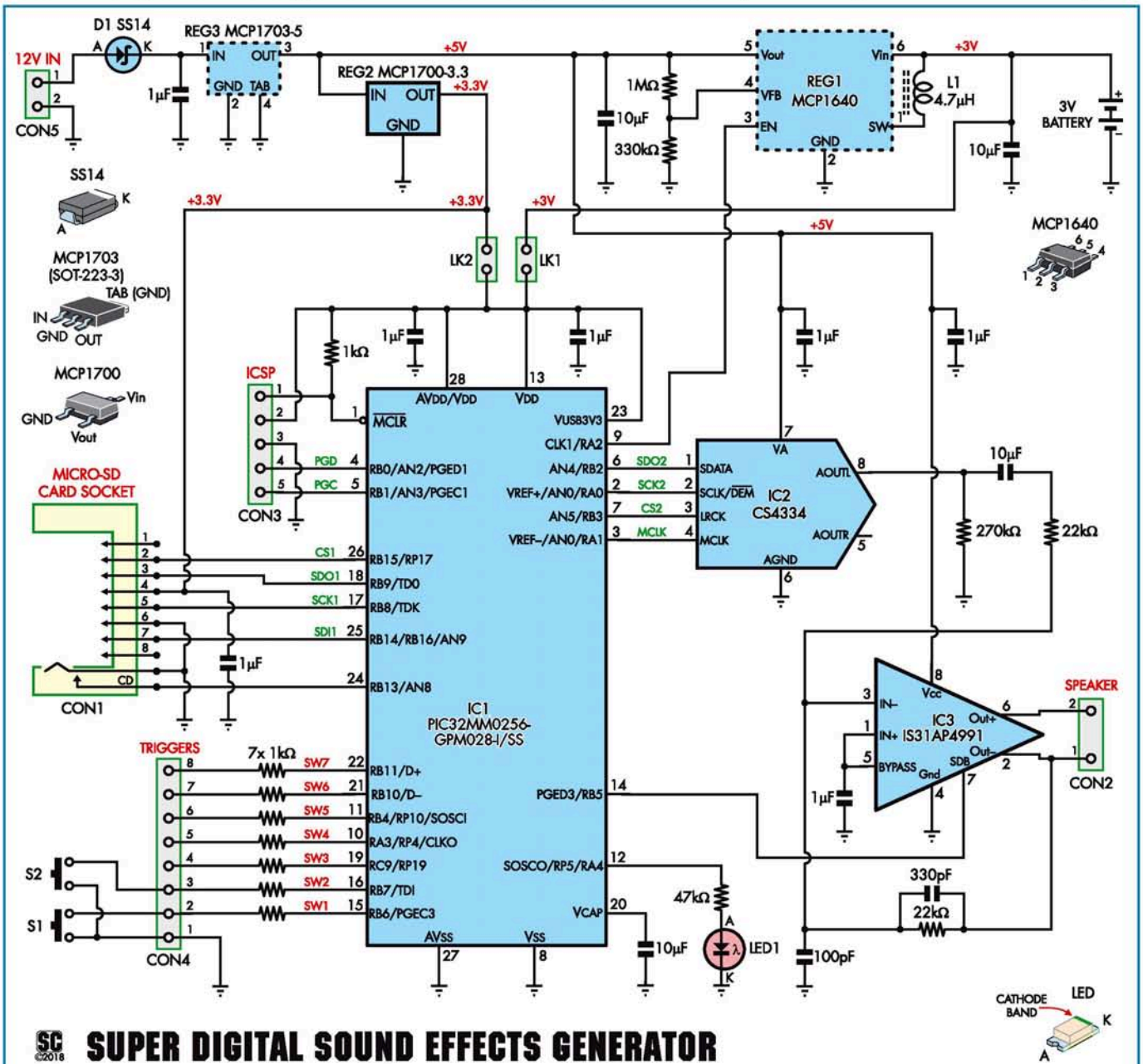


Fig.2: compare this complete circuit diagram to the block diagram, Fig.1. Either REG1 or REG3 is fitted (not both) to provide the 5V rail which powers IC2 and IC3. The seven series resistors between IC1 and CON4 help to protect IC1 against damage from static electricity or voltages outside its normal operating range of 0-3V or 0-3.3V (depending on the supply option).

once when triggered and will stop when the card is shut, preventing unnecessary battery drain.

The use of up to seven WAV files in single or looped playback mode can provide seven custom voice prompts or warning sounds controlled by separate triggers. These could even include DTMF tone sequences (there are online DTMF tone generators available) which automatically dial a preset phone number, with the unit's output fed into a telephone line through an appropriate coupling method.

It isn't even necessary to have more than one WAV file on the card to use all the inputs. Each input can be set to use the same WAV file in different modes or at different volumes. We'll go into the detail of what each of these modes does and how they are set up later on.

General operating concept

The circuit diagram, Fig.2, shows the overall configuration of the Super Sound Effects Module. At its heart is PIC32MM0256GPM028 microcontroller IC1, featuring 256kB of flash program storage and 32kB of RAM. The combination of a 32-bit processor and ample RAM are essential to the effective sampling and mixing required by this project.

The PIC32MM series is designed for compact low power applications and runs at only 24MHz from an internal fast RC oscillator (8MHz), with the oscillator's output multiplied by a PLL (phase-locked loop). The large flash storage space allows us to fit the required software along with a few "bonus" samples which can be used without an SD card inserted.

The PIC communicates with an SD card inserted into micro socket CON1 using one of its two hardware SPI ports. Besides the four usual SPI lines (clock, data in, data out and select), there is just one additional connection to the SD card socket, allowing the micro to sense the state of its "card detect" microswitch.

This pin is shorted to ground when a card is inserted and is otherwise open circuit. An internal pull-up current is enabled by the software in IC1 which holds this pin high when the card detect switch is open, allowing the software to read the digital pin state and determine whether a card is present.

Once the audio data has been read off the SD card and processed by the micro, it is fed to a stereo digital-to-analog converter, IC2 (CS4334). The sound effects module operates in mono but most good quality audio DACs are stereo so we simply feed the chip identical data for each channel (this is a hardware option on the micro) and use just one of the DAC's outputs (AOUTL) at pin 8.

The reverse side of the Digital Sound Effects PCB has a few components fitted including switches S1 & S2.

The audio from this pin is fed to a mono bridged amplifier IC, IC3 (IS31AP4991). The audio signal is AC-coupled with a 10µF capacitor as the DC bias levels of the DAC and amplifier will not necessarily be the same (although they will both be similar, at around 2.5V).

The signal also passes through a 22kΩ series resistor which forms a low-pass filter with the two capacitors connected to IC3's pin 3 inverting input, as well as setting the bridged amplifier gain to two times, as it is the same value as the 22kΩ resistor from the pin 2 output back to the inverting input.

The 22kΩ series resistor and 100pF capacitor to ground form a low-pass filter with a -3dB point of 22kHz, reducing the DAC's sampling artefacts. The 330pF capacitor across the 22kΩ feedback resistor also provides a low-pass filtering effect as well as helping to stabilise the amplifier and prevent oscillation.

A 1µF capacitor from pin 5 of IC3 to ground stabilises its half-supply reference, helping to prevent any noise which may be present on its supply rail from being injected into the amplified outputs. It also has a 1µF supply bypass capacitor close to the IC, to provide it with bursts of current during audio transients. IC3 drives the 8-ohm speaker directly, which is connected to its bridge output pins 6 and 2, via pin header CON2.

The amplifier IC is capable of directly driving an 8Ω speaker to more than 1W, assuming the power supply is capable of delivering the current. Depending on how the circuit is powered, the supply may not be capable of delivering the required current of 250mA or more. In this case, a higher impedance speaker can be used, or a resistor can be connected in series with the speaker to limit peak currents; more on this later.

Alternatively, you can connect a piezo transducer in place of the speaker. The sound quality will not be as good but the efficiency is higher and the amplifier has no trouble driving such a load (which is capacitive).

Digital audio interface

We operate the DAC (IC2) with a sampling rate of 46.875kHz. This may seem like an odd value; more typical sampling rates would be 44.1kHz (as used for CDs) or 48kHz (as used for DVDs). The reason for the unusual value is that this is an integral fraction of the maximum clock speed of the microcontroller, IC1 (24MHz). Hence, it can easily be produced by the micro using one of its internal timers/counters.

The DAC IC requires a "master clock" which is a multiple of the sampling rate and the multiple must be one of several fixed ratios supported by the IC, specifically, 128, 192, 256, 384 or 512 times. If we run the micro at the full 24MHz and choose the 512 times value for the master clock, that allows us to have a sampling rate of 46.875kHz (24MHz ÷ 512) and this is the one that we have chosen.

The other multiplier values give a higher sampling rate unless we lower the microcontroller clock speed but that would then slow down its processing. So we decided that the values specified above were the best choices.

As well as the master clock signal, which is fed to its pin 4, IC2 expects 16-bit digital audio data in I^2S format fed to pins 1-3, where pin 1 is the audio data input, pin 2 is the bit clock (which runs at 32 times the sampling rate, ie, for two channels with 16 bits of data each) and pin 3 is the left/right clock which runs at the sampling rate and indicates when the left channel data is on pin 1 (LRCK low) and when it's the right channel data (LRCK high).

Microcontroller IC1 has specific hardware for generating digital audio signals, including I^2S format. It does this using one of its two hardware SPI (serial peripheral interface) units. I^2S is similar to SPI but there are a few minor differences, such as the need to generate the extra left/right clock output signal.

So the serial data (to pin 1 of IC2) and bit clock (to pin 2) are generated in virtually the same manner as they would be in SPI mode, from output pin

Parts list – Super Digital SFX

1 double-sided PCB, coded 01107181, 55 x 23.5mm
1 SMD microSD card socket (CON1) [Altronics P5717 or similar]
2 mini SMD two-pin tactile pushbutton switches (S1,S2) (optional) [eg, Switchtech 1107G]
1 5-pin header (CON3) (optional, to program IC1)
1 speaker, size to suit (8Ω or greater) ***or*** piezo transducer (see text)
1 two cell AAA or AA battery holder (optional)

Semiconductors
1 PIC32MM0256GPM028-I/SS programmed with 0110718A.hex, SSOP-28 (IC1)
1 CS4334 16-bit stereo DAC, SOIC-8 (IC2)
1 IS31AP4991 mono bridged audio amplifier, SOIC-8 (IC3)
1 MCP1640 boost regulator, SOT-23-6 (REG1)*
1 MCP1700-3.3 LDO linear regulator, SOT-23 (REG2)
1 MCP1703-5 LDO linear regulator, SOT-223 (REG3)#
1 blue SMD LED, 3216/1206 package (LED1
1 1A schottky diode, DO-214AC (D1) [eg, SS14]#
 # only required for 5.5-15V DC powered version

Capacitors (all SMD X7R ceramic, 6V, 2012/0805 size)
4 10µF
7 1µF 16V
1 330pF
1 100pF

Resistors (all SMD 1%, 2012/0805 size)
1 1MΩ 1 330kΩ 1 270kΩ 1 47kΩ 2 22kΩ 8 1kΩ
1 0Ω (LK1/LK2)

Inductors
1 4.7µH chip inductor, 3226/1210 size package, 1A+ (L1) [eg, Taiyo Yuden CBC3225T4R7MR]*
** only required for battery-powered version*

6 of IC1 (configured as SDO) and pin 2 (configured as SCLK) respectively.

Pin 7 of IC1 would normally be the SPI chip select (CS) output but in audio mode, this becomes LRCK.

The MCLK signal for IC2 is produced from digital output pin 3 of IC1 but does not come from the audio signal interface. Instead, this pin is configured as a PWM output using a timer derived from the micro's system clock. Since this same clock is used to generate the I^2S audio signal clocks, the signals are synchronised and the ratios are locked.

When the DAC is not being used and the micro is in sleep mode, since the micro is no longer driving the MCLK and LRCK pins with square waves, IC2 automatically goes into a low-power sleep mode. The amplifier can also be put into a low-power mode by the micro by pulling its shutdown input (pin 7) high. This is connected to digital output RB5 (pin 11) on IC1.

Trigger inputs

Sound effects are triggered when one of the digital input pins 2-8 on pin header CON4 change state; normally they are triggered by being pulled low but this can be inverted with a software option.

Each of these pins connects to a digital input on the micro via a 1kΩ resistor which is present to protect the microcontroller in case a voltage outside the range of 0-3V is applied to one of these pins, by limiting the current through the micro's input clamp protection diodes.

Each of the micro's seven digital trigger inputs is configured by the software to be supplied with a small pull-up current which flows from V_{DD}. This holds those input high unless they are externally pulled low. So pin 1 on CON4 is tied to ground so you can trigger the sound (in the default mode) by shorting pin 1 to one of the other pins.

This can also be done by an external switch, relay or transistor. If onboard tactile pushbuttons S1 and S2 are fitted, they can be used to trigger the first two sound effects channels.

Power supply

The power supply arrangement on this board is a little complicated since it is designed to be set up for two different power sources: either a battery of around 3V (eg, 2 AA or AAA cells) or a 5.5-18V DC supply from a plugpack, model railway train tracks (DC or rectified and filtered AC) or the rectified and filtered output of a transformer or similar.

When powered from a ~3V battery, link LK1 is shorted and thus microcontroller IC1 is powered directly off the battery. When in sleep mode, it draws a tiny amount of current (under 1µA) so this connection will not drain the battery.

Switching boost regulator REG1 is also fitted for battery use. When in sleep mode, the micro keeps this shut down by driving its pin 3 enable input low, from its RA2 digital output (pin 9). When that output goes high, the boost regulator is enabled and it produces 5V at its pin 5 output.

No external transistors or diodes are required since this is a synchronous regulator, with all switching done internally. This also maximises efficiency. The external components that are required are inductor L1 which is used as an energy storage device and to boost the voltage, 10µF ceramic input bypass and output filter capacitors and a 1MΩ/330kΩ resistive feedback divider which sets the output voltage to 5V.

The 5V supply then powers the DAC (IC2) and audio amplifier (IC3). IC2 requires a 5V supply while IC3 can operate from 2.7-5.5V but will have a greater output swing and thus better power delivery when operating at higher voltages.

This 5V supply is then reduced to a regulated 3.3V supply to power the microSD card by linear regulator REG3.

While boost regulator REG1 can work with an input supply as low as 0.65V, since IC1 is also powered from the battery this means the minimum operating voltage is 2.0V.

Typical microSD cards will accept signal levels down to 2.0V, although they require a minimum supply voltage of 2.7V, so the card should not be the limiting factor on the minimum operating battery voltage.

With REG1 shut down, the only components drawing power are IC1 and REG1, both of which have very low current demand in the sleep/shutdown state. Total standby current is just a few microamps. Note though that this has the disadvantage that the microSD card must be initialised immediately upon the device being triggered which means there can be a delay in play-

ing back the first sound. This can be reduced by either pre-buffering some sounds in RAM or by keeping the micro awake and the regulator active for some time after each trigger even, so it's ready to be re-triggered. We'll explain these schemes in more detail later.

Alternative power supply arrangement

If a higher supply voltage is available then boost regulator REG1 is not necessary and should not be fitted. Reverse polarity protection diode D1 and 5V linear regulator REG3 are fitted instead. The DC supply is connected to pin header CON5 and the 5V output of REG3 powers IC2 and IC3.

REG2 supplies 3.3V to the microSD card as before but in this case, LK2 is inserted rather than LK1 and so microcontroller IC1 also runs from the output of REG2.

With this supply configuration, the sleep current is higher because IC2, IC3, REG2 and REG3 are always powered however these are all capable of entering low-power sleep mode or have a low quiescent current.

The microSD card is also powered continuously, however, this is kept in a low-power standby state unless it is actually being used.

So the sleep mode current with this power supply arrangement is higher than with a battery and depends on how much current the SD card draws in its idle state. IC2 draws around 45µA and an SD card is usually around 0.5mA in standby mode, for a total that's typically well under 1mA.

Note that REG3 is physically larger than the other regulators (in an SOT-223 package rather than SOT-23) and it is soldered to a solid copper plane. This is necessary since, at higher input voltages (eg, 12V), its dissipation could be substantial.

During sound effect playback, the circuit could draw more than 100mA and with a 12V input and 5V output, that's in excess of 0.7W of dissipation.

Software details

The software for this project is quite complex as it provides many different configurable features and does a lot of "real-time" processing in order to read and play back multiple files with different sampling rates and looping options at the same time.

Practically all of the 32KB RAM is used to buffer samples from the microSD card and the spare flash memory is filled with some useful audio samples as well.

Initialisation

On startup, the software performs a number of initialisation tasks. It needs to set the initial state of the LED drive pins, control pins for REG1 and IC3 and microSD card interface pins. Both internal SPI peripherals need to be set up as one is used for communication with the SD card and the other, with the DAC. They also have re-mappable I/O pins so those need to be set to the correct external pins.

Since the only interrupt service routine used by the software is for feeding audio data to the DAC and this should not be interrupted, the interrupt priority is set to the highest possible level.

Pin 3 is set up as a 12MHz clock output to provide the master clock (MCLK) for the DAC. This utilises the SCCP4 peripheral (single ended capture/compare/PWM) with a prescaler of 1:1 and a period of two clocks (the system clock is 24MHz). The rising edge register is set to zero and the falling edge register to one, meaning that the output alternates on each clock pulse, giving a 12MHz square wave.

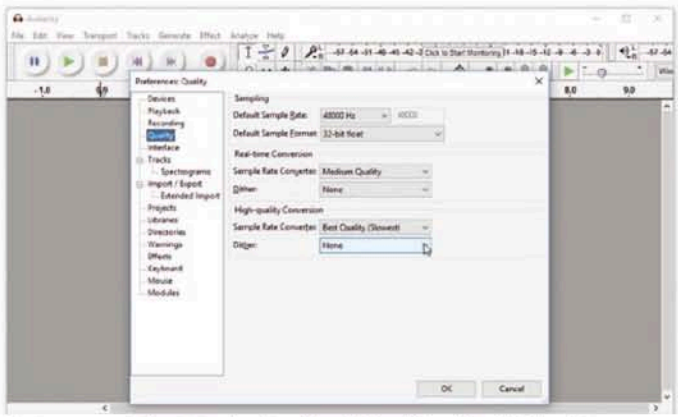
The microSD card requires power before it can be initialised, so as soon as the unit is triggered, the control pins for REG1 and IC3 are brought high to switch them on. The software then checks the level on the microSD card detect pin and flashes LED1 to indicate an error if it is not found. The card initialisation procedure then starts and once the card is ready, the configuration file is then found and loaded.

The configuration file consists of lines of text which are then "parsed" one at a time, to extract the required settings, then stored in RAM to be referred to later.

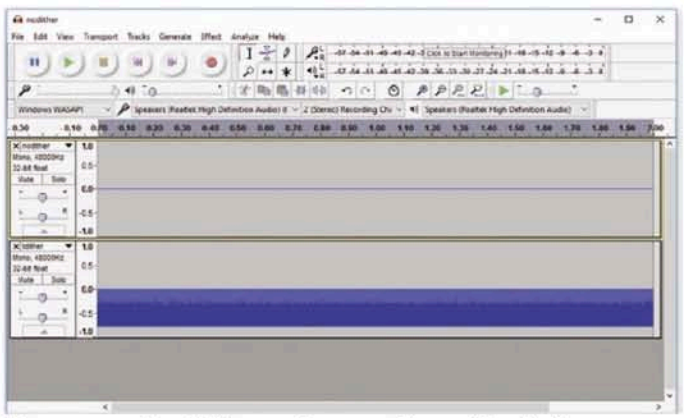
Once that is complete, the interrupt which produces I^2S data for the DAC is activated and then the Super Sound Effects Module is ready to operate.

There are three 512-byte buffers for each of the four playback channels (ie, twelve buffers total). The interrupt service routine (ISR) checks whether there is any audio data to be played back and if so, applies the appropriate volume for each channel and mixes the resulting samples.

The mixed sample value then has the master volume applied and is clipped to remain within the -32768 to +32767



It turns out that Audacity (by default) adds 'dither' to files as it saves them to spread out quantisation errors on downsampling. Unfortunately the dither is audible, especially for 8-bit samples. To turn off dithering, select Preferences from the Edit menu, and set Dither on High-quality Conversion (here, High-quality Conversion means saving rather than playback) to none.



You can see the difference by exporting a file of silence as 8-bit WAV before and after the change. Reopen the files (as we have done here, and amplify each by 40dB. The one without dither remains at zero, while the file with dither has an obvious hiss. 16-bit files also have dither applied but the effects will not be as pronounced as the effects for 8-bit files.

range for 16-bit audio data.

If any clipping occurs, a flag is set which is picked up by the main loop and it operates to reduce the overall volume to limit distortion.

Main loop

With the DAC ISR handling audio output, the main program loop continues running. In addition to checking for the clipping flag, it also monitors each of the triplets of audio buffers. If one becomes empty and there is more data in the associated file, it fetches more data from the SD card to "refill" the buffer. This way, the ISR never "runs out" of audio data until it's time to stop playback.

After it fetches the data, it then resamples that data (using linear interpolation) to match the DAC's sampling rate of 46875kHz and also converts any 8-bit data to 16 bits, and stereo data is downmixed to mono.

The optimum WAV file format for use with this unit is 16-bit mono at 46875kHz, as this will not normally result in any re-sampling or downmixing. However, the use of 44.1kHz and 48kHz files will not result in much degradation.

Once it has ensured that all the audio buffers have data as required, the PIC then turns its attention to the seven digital trigger inputs. The behaviour of each input depends on the mode selected in the configuration file.

If it determines that an input has been triggered, it then checks if one of the four audio output channels is free. If so, the free channel is set up to play back the sound which has been configured to be triggered by this particular input. In doing so, it fills up that output channel's audio buffers before it actually starts playback, so that it will be able to fetch more data as they are emptied over time.

Once the buffers are empty and the source file(s) are exhausted, that channel is freed up for use by another sound effect trigger in future.

If an input is set up with one of the "attack-sustain-release" type configurations mentioned earlier then it is necessary to start playback of a second file once the first one has finished. In this case, as soon as the first file playback is finished and an audio buffer is free, the second file is opened and the audio buffer refilled. The same procedure happens once the "sustain" sample has finished playback.

If an input is set up to play files in round-robin or random mode then multiple files can be specified for that input. In round robin mode, the first time the input is triggered, the first file is played back. The second time it is triggered, the second file is played back and so on until the last file is played back, at which point the sequence restarts.

In random mode, a pseudo-random number generator is used to select one of the listed files to play back each time that input is triggered. Each subsequent trigger event may therefore trigger the same sound again or a different sound; there will be no obvious pattern.

If there is no audio being played back, the main loop starts a timer. Once that timer has reached a user-configured threshold, the unit goes into low-power sleep mode, powering down the SD card and anything else that's under the micro's control (including itself!).

Because we are not writing anything to the microSD card, the file handles and configuration data will can remain in RAM and do not have to be read off the card again, saving some time next time an input is triggered and the chip comes out of sleep mode.

Changing playback pitch

The trigger inputs connected to pins 5 and 6 of CON4 (ie, pins 10 & 11 of IC1) can also function as analog inputs. So one feature of the software is the ability to reprogram either or both of these inputs as analog voltage pins which control the playback speed and therefore pitch of the sounds triggered on other channels.

If enabled, the software periodically samples the voltages on the appropriate pin using IC1's internal analog-to-digital converter (ADC) and then uses this to "tweak" the sampling rate that's being used to play back the sounds for the configured channel.

For example, if we play it back at half of the actual sampling rate then the sounds will be one octave lower than normal (and will take twice as long to play back) while if we play it back at double the actual sampling rate, the sounds will be one octave higher and it will take half as long to play back.

In reality, the sampling rate shift is not normally this extreme but it allows for engine sounds that change in pitch with speed and so on.

The trigger input connected to pin 4 of CON4 (ie, pin 19 of IC1) can function as the clock input for IC1's internal TIMER3 counter. This pin can be configured as a pulse counter input and the pulse rate (ie, frequency) can then be used to vary the sound playback rate.

Regardless of whether you are using an analog voltage or a pulse frequency to vary the sound playback rate and pitch, you can specify on a per-channel basis which is the controlling input, the control range of the voltage or frequency and the percentage change in playback rate which results.

Audible debugging

Since the unit has no display and only one LED, which can indicate just a few error conditions, we have also programmed the chip with an audible debugging mode. When enabled, it "speaks" its settings via the audio output, so that you can check to see whether it has been configured the way you have intended.

We have implemented this feature by using speech synthesiser software to produce samples for all the necessary words and numbers and then these have been stored in the PIC's flash memory.

So when you enable this mode, called "speakback" in the configuration file, at power up it will audibly list all of its settings and then you can listen to the output and see whether everything is as expected.

The only part of the configuration which isn't "spoken" is the file names. Each file mentioned in the configuration file is checked to see if it appears to be valid (ie, the name refers to a file that's stored on the SD card) and it will then say "OK" or "not OK" depending on whether the file has been found or not. Otherwise, all configuration parameters are read out for you to check.

Once you're happy that the configuration is correct, you can edit the config file and switch this mode back off, to get normal operation.

Next month

Phew! That's enough to digest for one month . . . but having read all that, we trust you'll agree this is one very clever little device (little being the operative!).

In part two next month, we will get onto the fun part: putting it together and full instructions for setting up and using the new Super Sound Effects Module. SC

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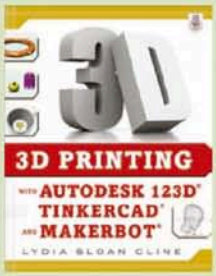

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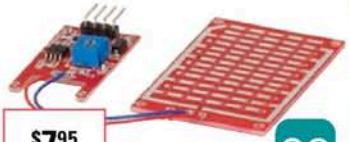

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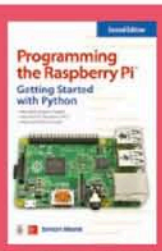

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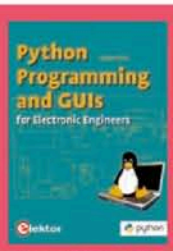

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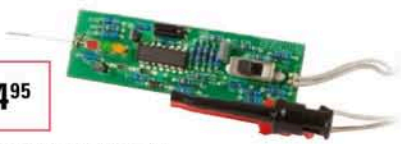

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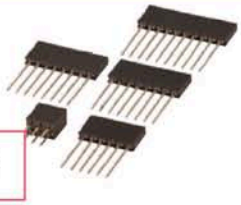

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- 3.5 Digit LCD display
- 200,2000,20000, 50000 Lux/Fc

$24.95

CAT III NON-CONTACT AC VOLTAGE DETECTOR QP-2268

Detects AC voltages from 200 to 1000V. The unit will glow green when safe, and flash red and beep when voltage is detected.
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Easily monitor your vehicles battery voltage and current draw. Connection is via spade terminals. 5-30VDC.

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5.5MM TIP, 125MM LONG
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- ✔ Rapid response 470kHz Curie heating technology
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- ✔ Under 10 second heat-up
- ✔ Rapid recovery from soldering load. No overshoot
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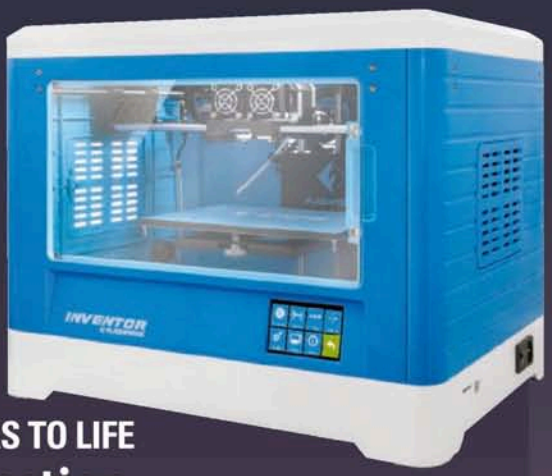

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- 10-60W Equivalent electrical power
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Includes magnetic holder, Phillips bits, slotted bits, torx, tamperproof, pin drive, wing nut driver etc. Suits standard 1/4 inch driver handle.

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60% Tin / 40% Lead. 1.0 & 0.71mm available. Resin cored.

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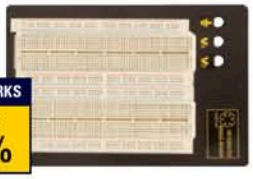
WB-2001 / 05 **REG $19.95 EA. CLUB $14.95 EA.**
30m roll. Available in white or black colour.



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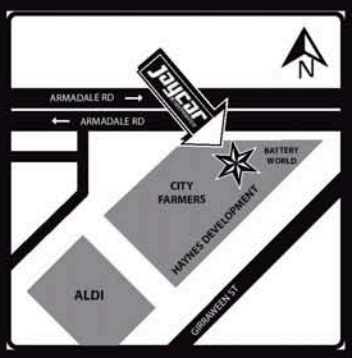

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock. Savings off Original RRP. Prices and special offers are valid from Catalogue Sale 24 July - 23 August, 2018.

SERVICEMAN'S LOG

Roped into fixing a friend's dishwasher

Dave Thompson*

Dishwashers are ostensibly quite simple mechanical appliances with pumps, solenoids, a timer and a little thing called a "wax motor". What's a wax motor? I hear you ask? I didn't know the answer either and this was my introduction to fixing a friend's dishwasher. Fortunately, I did not have to fix it before we had dinner.

I was invited to the dinner by an engineer acquaintance I hadn't seen for a while, which was a pleasant surprise. Over dinner, the conversation veered toward work. Then my host asked if I knew anything about dishwashers.

Sensing the loaded question, I informed him that I didn't know much about them, never having had one apart.

When I asked the reason, he told me his dishwasher was just out of warranty (of course) and had started misbehaving. The powder dispenser was no longer opening, meaning the wash cycle was completing without any powder or rinse-aid being introduced. Could I perhaps take a look?

I wonder if mechanics who visit their friends get asked to replace a leaky head gasket after dinner. Or whether doctors out for a nice evening of food and wine with acquaintances end up getting roped into doing a quick surgical procedure on the dinner table. But I digress...

I had a quick look at the dishwasher, checking the patently obvious, ie, that the powder/tablet dispenser's door could indeed open and close freely. Beyond that, we were into (for me at least) a technical grey area.

While I'd have thought nothing of opening the appliance up there and then, some serious shade was being thrown my way by the other half, reminding me that we'd come for dinner, not to work!

I arranged a time to go and have a proper look, secretly relieved as I never did like going into anything blind, especially with someone looking over my shoulder.

At least I'd now have time to look into dishwasher operations and potential problems and solutions before committing to a repair.

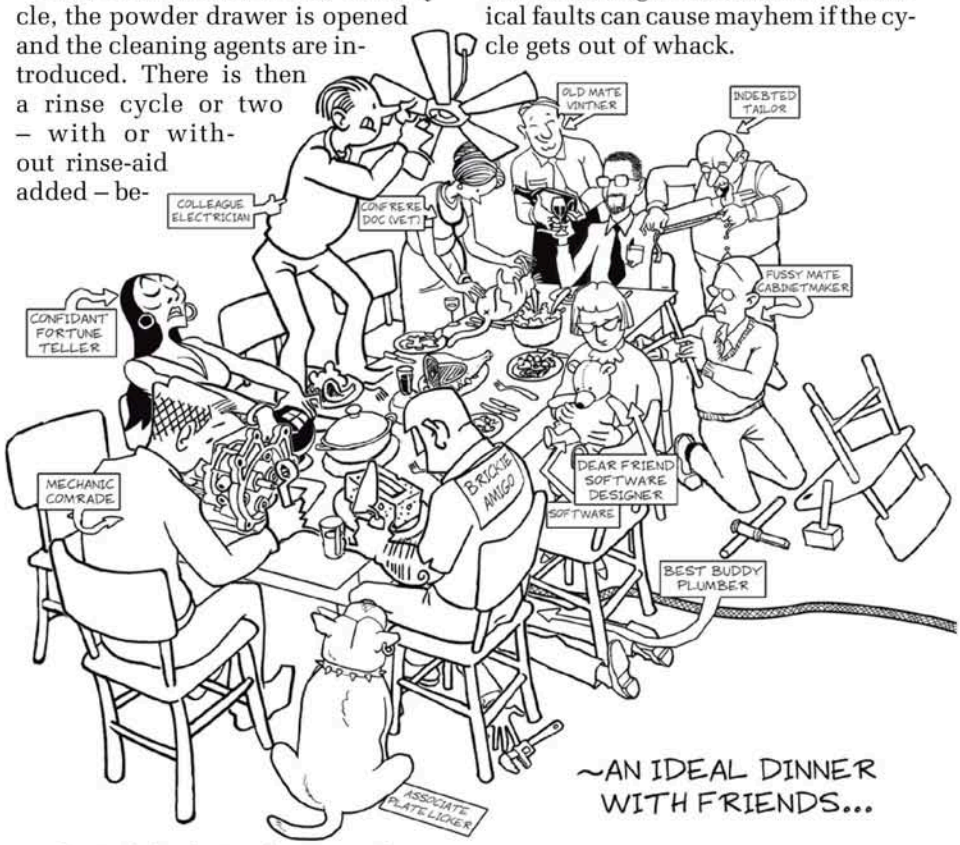
Dishwashers for dummies

These appliances turn out to be a very simple idea cleverly implemented. Essentially, they are just a watertight box with trays that hold dishes at different levels while heated water is sprayed around by (usually) water-pressure powered rotary nozzles.

At a certain time in the wash cycle, the powder drawer is opened and the cleaning agents are introduced. There is then a rinse cycle or two – with or without rinse-aid added – before the water is pumped away and the dishes gradually dry off in the warmed cupboard.

Some models may also automatically pop the door ajar during the final, drying phase to aid moisture evaporation; some also use ultra-violet light as an anti-bacterial "sterilisation" feature.

While that all sounds pretty straightforward, as with all appliances there are many potential things to go wrong. Leaks, blockages or electrical-mechanical faults can cause mayhem if the cycle gets out of whack.



Items Covered This Month

- Dishwashers for dummies
- Ants on the drive
- Earth leakage fault
- Heat pump repair

*Dave Thompson runs PC Anytime in Christchurch, NZ.
Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

In a worst-case scenario, we could end up with a shed-load of water all over the kitchen floor, something I can tell you from experience is what you don't want happening.

The majority of my kitchen furniture is made from melamine-coated particle board and while the sides and edge-banded areas may be watertight, the bare edges of all the cabinets sitting on the floor act like a sponge to any moisture they are exposed to, so a few centimetres of standing water doesn't do them much good!

If exposed to too much moisture, the edges swell up like the half a digestive biscuit I always drop into my mug of tea, causing drawers and cupboard doors to stick and, in more serious cases, entire cabinets to sag and bow. I know this because it happened to us and repairing that kind of damage is difficult and expensive.

Modern dishwashers utilise various sensors and onboard computers to control all the various functions, while some older or less-expensive types use mechanically-operated timers and actuators instead.

Some early models used bi-metallic strips to regulate water flow or open the dispenser when the right water temperature was encountered, while newer or more sophisticated units use electronic temperature sensors or electrical and thermally-operated solenoids called "wax motors" to achieve the same thing.

Other older types used mechanical timers to pop the powder drawer at a certain point in the cycle so there is plenty of scope for variety.

The meat of the repair

The dishwasher in question, a Haier branded unit, is regarded as a basic but usually reliable unit if internet chatter is to be believed. This model has a very simple control panel: an on/off pushbutton, a half-load button and a single dial on the right-hand side for different cycle settings; no fancy bells and whistles to complicate things (or go wrong!).

According to my research, it utilises a wax motor drawer-release mechanism and the problem was most likely to be the heating coil for the wax motor going open-circuit (more on this below). If not that, there is likely some mechanical reason for the drawer not opening. The only way to know for sure was to open the thing up and get probing with a set of eyeballs and a multimeter.

Thankfully, this dishwasher manufacturer has its act together and everything to do with working on this unit was a breeze. For starters, getting it out was easy; the rear two support rollers slot into corresponding locating/holding clips that are screwed to the floor, while the front is supported by wheels; an arrangement that prevents the dishwasher moving around in any direction once installed.

Grabbing the edges of the closed door and pulling straight out was all it took to roll the unit clear of the bench cavity. The power cable was plugged into a socket located on the wall up behind the unit, while the water and waste hoses fed through a sizeable hole in the adjacent cabinet wall. There was plenty of slack in all the leads and hoses and getting behind it to disconnect or unplug them was no problem.

I removed the power plug but left everything else in place; no point tempting fate by needlessly disconnecting hoses and potentially introducing leaks if I didn't have to.

There were no visible screws on the outside of the cabinet but upon opening the door I could see everything I might need to undo was easily accessible from the inside and along the edges of the chassis. Hopefully it wouldn't come to that, but either way the door front would have to come apart, as that is where the powder-drawer dispenser and actuator lives.

Like most white-ware, the thin steel panels are held to the main frame using medium-to-large PK-style countersunk screws. The coarse thread pattern on these fasteners is excellent for this type of sheet-metal joinery. However, due to their size and the screwdrivers typically used to fit the screw heads, they are very easy to over-torque during re-assembly.

This often leads to servicemen finding oddball-sized screws utilised, as the original's mounting holes are stripped and ever-bigger fasteners are used by over-enthusiastic re-assemblers. I've even found the odd large wood-screw holding fridges or oven panels together! Thankfully, it appeared I was the first serviceman into this appliance, so no mismatched screws to deal with here.

Half a dozen removed screws later, the faux-enamelled front panel fell away from the pressed-steel interior door section and sprung, tubular-steel support frame, revealing some very non-technical components.

Getting down to nuts & bolts

There were several sound and vibration-deadening carpet swatches stuffed into cavities, a couple of purpose-shaped plastic foam packing pieces and multiple wiring looms coming from beneath the bottom door hinge and going off to points (for the moment) unknown.

One small loom disappeared into some sound-proofing material about half-way up the door, to the barely-visible, injection-moulded plastic dispenser assembly. While this was mostly buried in foam packing, I spotted the wax motor mounted on the left-hand side of the dispenser.

According to Wikipedia, a wax motor is "a linear actuator device that converts thermal energy into mechanical energy by exploiting the phase-change behaviour of waxes."

It apparently contains a small tube packed with wax and a piston; heating the tube at a certain time into the wash cycle, usually electrically via a thermistor, causes the wax to gradually expand, forcing the piston to extend, which pushes on a plastic bell-crank and, via a lever arrangement, disengages a sear which then allows the powder drawer to spring open.

It is a simple yet effective method of opening the dispenser. In some models, a secondary actuator allows rinse-aid to enter the cabinet during the rinse cycle.

The powder drawer itself sits opposite the wax motor assembly on the other side (inside) of the door panel and a rubber seal keeps any water from entering the door cavity. As the drawer is opened by a spring and manually shut once the powder or pellet is added, it doesn't take much to release the retaining sear and pop it open.

Once open, the drawer is usually stopped by and rests under the top dish tray, a position that helps guide water into the dispenser to ensure all the powder and/or rinse-aid is washed out.

On many dishwashers, when you open the door to remove the dishes, you hear the dispenser door flick open all the way, a somewhat disconcerting sound if you haven't heard it before.

However, in this case, the drawer remained closed. Testing it in-situ

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would be a problem, as running the appliance through a wash cycle is both time-consuming and inconvenient, especially since I had the covers off and it was sitting in the middle of the kitchen floor.

What I needed to do was to see if I could measure the resistance of the thermistor which heated the wax to operate the wax motor; this would at least tell me if the thing was still electrically alive. If it was, the problem could lie with the wiring, the controller board or something mechanical.

I removed the leads from the motor terminals and with my trusty analog multimeter set to the 10Ω range, I placed one probe on each of the terminals.

I measured roughly 2kΩ, which according to Google (such a clever chap!) is about average. I wasn't too concerned with the actual resistance at this point, as long as it wasn't at either extreme; I just wanted to know if the motor had continuity, which it did.

The next step was to see if it actuated and to do that, I'd need to add power. The problem with this is that applying mains voltages to an in-place component using a pair of flying leads is a bit hairy.

Once bitten, twice shy

Many years ago, I vividly recall my brother and me, who were just old enough to get into trouble, messing about in Dad's workshop. My brother had found and wired up a mains plug, or perhaps just cut and stripped the leads of an existing cable and plug, while I watched over his shoulder.

We'd found a bulb after rummaging amongst Dad's bits boxes and were keen to fire it up, the way we'd seen him do it many times before – or so we thought. What we had done is inadvertently created what olde-worlde servicemen – in their typically dry way – call a "suicide lead" or "death cord". In other words, a cord with a mains plug at one end and bare wires (or alligator clips) at the other.

I must admit to possessing such a lead, which is typically used for testing valve-based equipment. But for obvious reasons, it makes me extremely nervous. My modern version has a crocodile clip to connect Active and Neutral to the equipment I'm testing but as kids back in the workshop, we just used bare wires and I held the bulb while we each applied one wire to one of the bulb's terminals.

It lit up, albeit extremely briefly and with the shock of the brilliance of it, I reacted and touched my lead to my brother's. Of course, this splattered and crackled and arced, scaring the bejeebers out of us and temporarily blinding me as well; a situation made worse by the fact the workshop was now plunged into darkness as all mains power went out.

Yikes! We were in for it now! I envisaged all manner of trouble was about to befall us and to this day remember the unusually stern talking to we both received from Dad. Not only were we told not to mess about in his workshop with anything we didn't understand, we were especially not to go anywhere near anything to do with mains-level voltages.

He then showed us how he powered up bulbs with a battery and encouraged us to experiment with that but not to mess about with anything that plugged in.

He also demonstrated how easily we could have killed ourselves by using his multimeter to demonstrate the voltage from the mains socket. That made me paranoid enough to still be extremely wary of it today.

The moment of truth

I was going to use my suicide lead to test the wax motor but not with direct mains voltage. I'd brought my autotransformer along to use with it, and while the output could still easily kill me, I made darn sure the connections to the wax motor were attached properly and well-insulated from anything else before cranking up the juice.

In order for this wax motor to fully actuate, it needs around 230-240VAC which is usually supplied at the right time in the cycle by the controller board. For testing, I dialled in 240VAC (indicated) on my non-Variac branded variac and waited. After a short time, the motor's plunger slowly deployed, moving the plastic lever system. However, the drawer remained closed.

From what I could see, the lever system didn't move far enough to trip the door mechanism. From this, I could deduce we were likely looking at a mechanical fault.

I removed mains power and while the motor was still warm enough, manually moved the solenoid's plunger as far as it would go; while some of the links go off to the rinse-aid dispenser, I could see the bell-crank and cam arrangement that opens the dispenser door.

The plastic arm that trips the drawer release didn't move far enough to open it, though it did if I gave it some extra help. I took a closer look and could see the pivot pin on one of the levers was out of whack. It was either misaligned from new or slogged out, I couldn't tell which. As no individual plastic parts are available for this dispenser, I would have to fix it if I was to avoid buying a costly replacement.

The lever popped off easily enough but it wasn't repairable using the original pin, so I removed it altogether and bored the linkage's moulded pivot point out. I found a suitable cap screw and self-tapped it well into the base, tightening it down enough to hold everything yet allow it to move freely. Now, when I manipulated the solenoid, the drawer popped open every time.

I didn't bother running another heated simulation, as I was sure this would work now. I'd spent a lot of time on this, and as the owner assured me he could reassemble everything, I left him to it.

However, I received a text message later that night saying that while the dispenser now worked fine, the dishes were still not as clean as before. I dropped by the next day to check it out and discovered that while he'd had everything apart, he removed the upper and lower rotating spraying arms in order to better clean them, but had re-assembled the bottom sprayer with the holes pointing downwards!

After reversing them, a test wash cycle proved everything was working properly. Whew!

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

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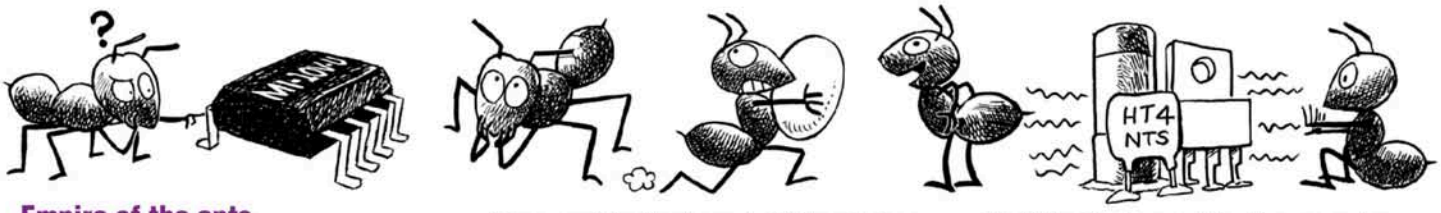


Empire of the ants

J. R., of Woy Woy, NSW, recently fought a pitched battle with a small but numerous army of invasive critters which threatened to overheat and gum up his electronic equipment. He did not welcome these new insect overlords and eventually banished them from his domain. Here is how it went down...

My "man-cave" is in our garage which I share with my car. The walls are bare single brick and although it gets a bit nippy in the colder months, the insulated ceiling helps a bit. I have a desk, workbench and adjustable steel shelving and I keep it all pretty neat.

We get a few mozzies and the odd fly in the warmer months but they are mostly dispatched with a very distinct zap by my high-voltage bug killer with UV attracting light. Ants are a different problem though.

Ants need food and shelter and it seems they like to be warm. Wifey prefers a minimal amount of technological stuff in the house so I keep my computer gear in the cave, including a couple of hard drives, the NBN modem and a router to network the house. Some of my gear stays on 24/7 and has a nice, stable temperature which is most attractive to insects, especially ants.

These industrious little beasts never seem to tire and they are mostly very good at staying out of sight as they move about. One day I was happily working away when a single black ant sauntered past.

I brushed it to the floor and thought no more of it until a while later when I spotted another one that I imagined might be looking for its mate. I thought there might be more about so I decided to look for their source.

I don't use the inbuilt keyboard or screen on my laptop so it hardly ever gets moved. I spotted a few more ants walking along a cable and then disappearing down a gap in the screen's hinge. Then I saw others leaving by the same path. Alarm bells were now ringing in my head and I immediately powered down the laptop and disconnected it.

There were probably a few alarm bells ringing in the ants' heads too because more appeared from the screen hinge and the keyboard. Without closing the screen, I picked up the laptop and took it outside to an old kitchen table we use for potting. A quick brush down of the tabletop and a strategically placed towel made a good clean work surface to open up the laptop.

Fortunately, I had a set of tiny Torx drivers that I bought when I replaced the hard drive with an SSD. More ants were now starting to leave their high-tech home and found themselves in a strange, very exposed place.

I undid all the bottom cover screws with the laptop sitting on the towel like an A-frame. I did this because I didn't want to squash any ants – the acid inside them would affect the components and PCBs.

I removed the bottom panel and saw what looked like millions of ants, their eggs and larvae all packed into every nook and cranny.

With the air now freely moving around them and the internals cooling down, it was every ant for itself! They were swarming all over the table, with many of them carrying an egg or larva.

I did not use any insect spray. I quickly set up an old vacuum cleaner I use in the garage and sucked most of them up. It took over an hour before they stopped appearing. I wish I had taken pictures whilst all this was happening and still can't believe how tightly packed they were.

What is more amazing is that there was zero impact on the computer – it had continued to function perfectly, with no overheating or errors at all! The ants must have been occupying my laptop for days or maybe weeks before I spotted a couple of their scouts.

I left the laptop out in the open for another hour or so to give the last stragglers time to leave. Once it was apparently emptied of ants, I removed everything that could be removed and found a few dozen more here and there. Some compressed air blew out a few more ants and eggs and eventually, I was satisfied that they were all gone.

I cleaned every surface I could with a cloth very lightly soaked in CRC 2-26. It is my weapon of choice against corrosion, moisture and electrical leakage and I feel sure the odour and the oily film would discourage future ant incursions. It doesn't go gooey either.

The only visible clue I could see left behind by the ants were white marks in tight places where the eggs had been and some CRC 2-26 on a cotton bud removed them almost totally. I left the laptop on my workbench overnight and reassembled it the next day. It has been working perfectly ever since.

But this story does not end here. A few weeks later I again noticed an ant on my desk. My response was swift. I whipped the laptop out of action and checked it thoroughly, but no ants, not even one – CRC 2-26 in action!

Nervously, I unplugged each item one by one and moved them outside. I saw no ants until I unplugged one of my hard drives and lifted it up to reveal a rectangular carpet of ants underneath. Yikes, not again!

Outside went the hard drive, onto the table, to wait for the ants to depart of their own accord. Back inside I quickly fired up the vacuum cleaner to suck up all the ants now running every which way on my desk. How had they been getting to the drive?

Well, the desk the drives are on is screwed to the wall with a dress strip making a nice dark tunnel out of the mortar line and delivering the ants to the hard drive. That strip is now gone.

I went back out to inspect the hard drive and only a few ants were exploring the tabletop. I peered into the drive's cooling vents and could see ants, ants, and more ants! This time they were not leaving, so using a few impromptu spudging tools made from scraps of fibreglass PCB and a screwdriver or two, I was able to carefully remove the case without stirring up the ants.

This time I took a couple of pictures too (as shown above). It was the same story as the laptop when it was opened – legions of ants with their eggs and larvae were now swarming all over the table and the vacuum cleaner did good once again.

It was then a simple matter to unclip and remove a metal shield to inspect around the hard drive and unplug the tiny controller PCB. Hard drives have dust-proof construction so no ants could get into the mechanism. As before, compressed air removed the remaining eggs and CRC 2-26 was used to clean up all contaminated surfaces and generally protect everything.

Reassembly the next day was easy. On testing the hard drive, I was relieved that the ants had caused no damage and the drive has been running 24/7 ever since.

You may think that was the end of it – no way!

Days later, more ants were observed in the man-cave, just wandering about looking for their next warm abode.

An extensive search eventually found millions more living in the extruded aluminium frame of my one and only window, right behind my desk, with a few hundred extra ants and eggs crammed into the little homemade headphone switch box which is screwed to the side of my desk.

I tried various surface sprays in and on the window frame and many days and dead ants later, they were still in evidence. Good grief, what does it take to get rid of them? I don't like the idea of long-lasting toxic chemicals being sprayed copiously where I spend a fair bit of my time.

After some trial and error, I eventually found that a Permethrin-based ant and wasp powder in a puffer pack was very effective and the safest way to go (Permethrin is a synthetic version of natural Pyrethrin). Result – no more ants – yay!

An earth leakage fault in the house

One morning, B. P.'s wife turned on the light switch but nothing happened. He thought it was probably just the globe that had failed but then another light could not be switched on...

The household appliances were still operating, displaying clocks and so on, so it obviously wasn't a blackout. I headed over to the laundry where our sub-board is located to see what was going on. The safety switch for the light circuits had tripped. I tried to reset it but it just tripped again, indicating a serious earth leakage fault.

We have a modern house and our electrical installation complies with the latest Queensland electrical regulations. We have two safety switches, one for the power circuits and one for lights. Three power circuits and two light circuits are protected by the safety switches.

Further investigations indicated that there was a fault on light circuit #1, which tripped the safety switch when on but light circuit #2 did not. So we could have light in part of the house for the moment.

The wiring in our entire house had been checked on three separate occasions by licensed electricians. The first time was when we had the underground power connected to the house, the second time was when we had the solar PVR system installed and the third time was a safety check following several electrocutions associated with the installation of foil insulation in house ceilings. So this was a new fault.

There was nothing for it but to head up into the roof space and have a look around and see if I could see anything. There's been a lot of activity in our roof over recent years, with the running of cables, first for the ABG satellite internet, then the interim NBN satellite internet, then again for telephone and network cabling when we got ADSL.

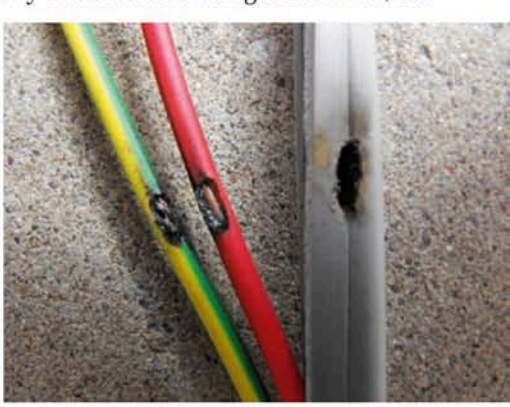
Also, as we'd been unhappy with the foil insulation that we had installed (it didn't seem to be effective during winter) we'd been putting "Earthwool" insulation under the foil. It had to be removed and re-installed on all of the above occasions too.

So, could any of this activity have caused the problem to occur? It seemed unlikely as it had been several years since anyone had done anything in the roof space. The next thing I thought of was rats in the roof. It's pretty common to find rodents in your roof space, so maybe a rat had eaten through a wire.

As I entered the roof space, I could see evidence of rodents and nothing stood out as problematic. However, I decided to lift the insulation and inspect all the wiring anyway. I could still find no problems. The wiring was still in excellent order with no sign of any damage whatsoever.

At this stage, I decided to give my mate Ray a call. Ray is a licensed electrician and he lives in town, but he often works in the Bay. Our place is between, and as it happened, he was just about to leave to do some work in the Bay, so he said he'd call in on his way past for a quick look.

When he arrived, he brought in his "megger" and tested the circuit, which gave a reading of 33kΩ. That's way too low and explained why the safety switch was tripping. I checked with my multimeter and I got a similar, but



higher reading, so we knew that there was an Active-to-Earth fault somewhere in the #1 light circuit. Now we just had to find it.

The quest begins

Ray headed off and said he would call in again on his way home when he would have a bit of spare time, to look into the matter further. When he got back, I suggested that we could start by disconnecting parts of the circuit until we found where the fault was. He agreed so we got started.

The #1 light circuit starts at the subboard and goes to the family room, kitchen, dining room, lounge room, entry, en-suite and master bedroom, with branches going to the end of the back verandah, the side verandah and the front verandah. So by disconnecting the wiring along the way, we would be able to isolate where the fault was.

We started in the family room, where Ray disconnected the circuit at one of the lights. This cleared the fault, so the fault was further on. After reconnecting the wiring there, we moved to the lounge room and did the same thing. This again cleared the fault, so we moved to the en-suite. This time, the fault was not cleared, so it was between the lounge room and the en-suite.

We'd skipped over the entry light, so we headed there and Ray found that the branch line from the light socket, which took power to the light switch near the front door, was where the fault was. Ray then removed this power wire at the light switch and tested the wire, which showed the fault.

So for some reason, the Active wire from the light socket in the entry to the light switch near the front door had an Earth fault. We would need to replace this cable and I had a cable drum with about 10m left in my shed. This was the older-style grey cable with thicker insulation, compared to the newer white slimline cable, so my left-over cable would match the original wiring.

We both knew that running this cable would be difficult, so Ray said that he would leave it with me and he'd call in again tomorrow afternoon to connect it up, once I'd run it between the two locations. In the meantime, he left that branch disconnected, so we would then have light in all the house except for the entry and the front verandah.

The next morning, I tied the end of the new cable to the old cable at the light switch and went up in the roof to pull the cable through, while my wife fed the cable up from the drum. Our roof is 22.5° pitch, so while there's enough room to get to the walls, it's a tight squeeze.

I managed to get over to the front wall with the aid of a plank set between the roof trusses which I could lie on. The first thing I noticed was a large snakeskin in the area where the cable ran down the wall but there was no damage to the cable at this point.

We often find snake skins around the place. There are times when we also find the owner of the skin, which is typically a carpet python, luckily a harmless type of reptile.

Occasionally, I have had to remove snakes from the house or the back verandah as my wife doesn't like them very much for some reason; I don't have any problems with them, particularly as they help to keep the rodent population under control. I usually just re-locate them clear of the house.

Anyway, I pulled the new cable up and ran it over to the light socket and poked the end through the ceiling, ready to be connected. I took the old cable down with me so that I could inspect it but initially, I couldn't see anything obvious.

I'd been expecting to find some severe damage to the cable, but on a quick glance, it looked like it was still OK. This indicated that there must be an internal fault in the cable itself.

I decided to rip the cable open to look for an internal fault and while I was doing this, I found the cause of the problem. Around 10 years ago, we'd been away for a few weeks and when we got home, I found that termites had tracked across the front verandah in one of the joints in the concrete and eaten the pine panel under the front door.

They were despatched quickly, but in any case, they can't do any structural damage to our house as it has a steel frame and is on a concrete slab. It would appear that when these pests had been present, they had actually chewed a hole in the cable in the front wall of the house.

As to why it had taken so long for this fault to materialise, I suspect it was because the weather has been exceptionally dry in this area for the last decade and we'd experienced several severe droughts during that time.

It's only last year that we've had unseasonal wet weather in spring, with

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very high rainfall and high humidity levels. In fact, it was mentioned on the weather report just recently that this was the wettest spring in decades. This must have caused any left-over termite material in the small hole to absorb moisture and become conductive.

When Ray came back to re-connect the wiring, I showed him the damaged cable. He was amazed and he said that he'd never seen anything like it in all the time he'd been an electrician. I told Ray that I'd previously seen wiring chewed by rodents, but I'd never heard of termites attacking electrical wires before.

Ray finished connecting the wiring and we once again had all our lights working. It was fortunate that we know Ray and we often do favours for each other, so that saved us quite a bit, compared to if we'd had to pay an electrician to locate and rectify the fault.

If we hadn't had the safety switch in the circuit, it is possible that the current flowing between the conductors could have caused it to overheat start a fire. Fortunately, the safety switch stopped it before it could escalate.

I had previously been wondering why there was a need for a safety switch on the light circuit, as it would be difficult for anyone to come in contact with a live wire, other than through carelessness when changing a light globe with the power still on. I can now see a very good reason for it.

Heat pump repair

Have you ever called in a repair technician, only to get the feeling that you know more about troubleshooting than they do? That must be how M. D., of Canberra, ACT, felt while dealing with multiple parties, none of which were able to find the fault in the household heating unit. He eventually managed to sort it out himself...

Our house is equipped with a reverse-cycle air-to-water heat pump. It is a three-phase device with about 12kW heating/cooling capacity. It's used for hydronic heating and cooling of the concrete slab in our house and we have several hydronic fan-coil units for conditioning the indoor air.

The heat pump is an imported Chinese model, rebranded and sold by a local distributor. It appears to be well built and has operated reliably for eight years. But towards the end of last summer, the unit began to intermittently trip. The system controller reported "Power phase error".

Throughout winter, this problem arose frequently, but unpredictably. At times, the unit would trip within minutes of starting, while at other times it would run for many hours without any problem. When the machine tripped, it could only be restarted by cycling mains power at the circuit breaker and this was becoming tedious.

The electrical design is straightforward. The heat pump compressor is switched by a contactor and this is driven by a control PCB. The unit has several safeguards such as a phase fail relay, overcurrent protection (in the contactor) and a system protection mechanism that monitors the heat pump for faults such as low/high refrigerant pressure and excessive compressor discharge temperature.

Having tired of this fault, I called the supplier. They suggested that the heat pump might have lost its refrigerant and to get a heat pump specialist to take a look at it. However, the low-pressure gauge was reading the correct pressure during operation. I called a heat pump technician. By connecting pressure gauges to the high and low-pressure service ports, he declared the system to be fine.

I then called an electrician. He checked phase voltages and currents and declared all to be in order. Without any real diagnosis, he thought that the phase failure relay would need to be replaced. The phase failure relay trips the main compressor contactor if the phase-to-phase voltage is out by 15% or if the phases are not in sequence. This was an expensive guess and did not fix the fault.

The electrician then sought to start replacing every electrical component upstream of the heat pump without further diagnosis. I felt it was time to take a more considered approach.

I called the supplier again. They suggested that I bypass the compressor safety switches to see whether that was the problem. Although these switches are low voltage inputs to the controller, I was not comfortable in operating the heat pump without these safeguards. In any case, the heat pump reported a power system fault.

The user manual is brief and offered little guidance. As is often the case with imported units, the English translation is ambiguous. The manual suggests that the heat pump is equipped with a system protection PCB in addition to the main control PCB. The circuit diagram in the door of the unit also shows this PCB but it was not present in the hardware!

The error we were getting was supposedly coming from this protection PCB, so I thought that the error message itself could have been in error.

I subsequently noticed that the compressor heating band was in poor condition with exposed wires where rats had chewed away the insulation. I disconnected the band, thinking that it may be the cause of the fault, but the unit still tripped intermittently.

It seemed to me that the control PCB was deciding to switch the compressor contactor off in response to an unexpected reading from some sensor. So I decided to monitor the low-voltage signals coming into the controller using a Maximite as a high-speed data logger. The contactor provided an auxiliary contact that I used to detect when the unit tripped.

I monitored the low and high-pressure switches, the over-temperature switch, the pump flow switch and the phase failure relay at 20ms intervals. Having observed several trip events, I could see nothing that would cause the unit to trip. I even powered the control PCB from an external battery to eliminate any power supply issues.

While checking voltages around the control PCB, I noticed that the signal from the over-temperature protection switch was sitting at around 1V and was unsteady. This was odd since all the protection sensors were supposed to be normally-closed switches. I had configured the Maximite to read the switches using digital inputs and so this had remained undetected.

I reconfigured the Maximite to read analog voltages and confirmed that the "switch" was producing a varying voltage as if it had gone high-resistance. Replacing the over-temperature cut-out switch solved the problem. The replacement cost about $5.

It was unsettling to witness lack of proper diagnosis by the electrical technician, the poor support offered by the supplier and the poor level of supporting documentation and the misleading error messages reported by the machine.

In the end, it turned out that I was the only person able to properly troubleshoot this system! But it certainly is a great relief to have heating back in place for the Canberra winter. SC

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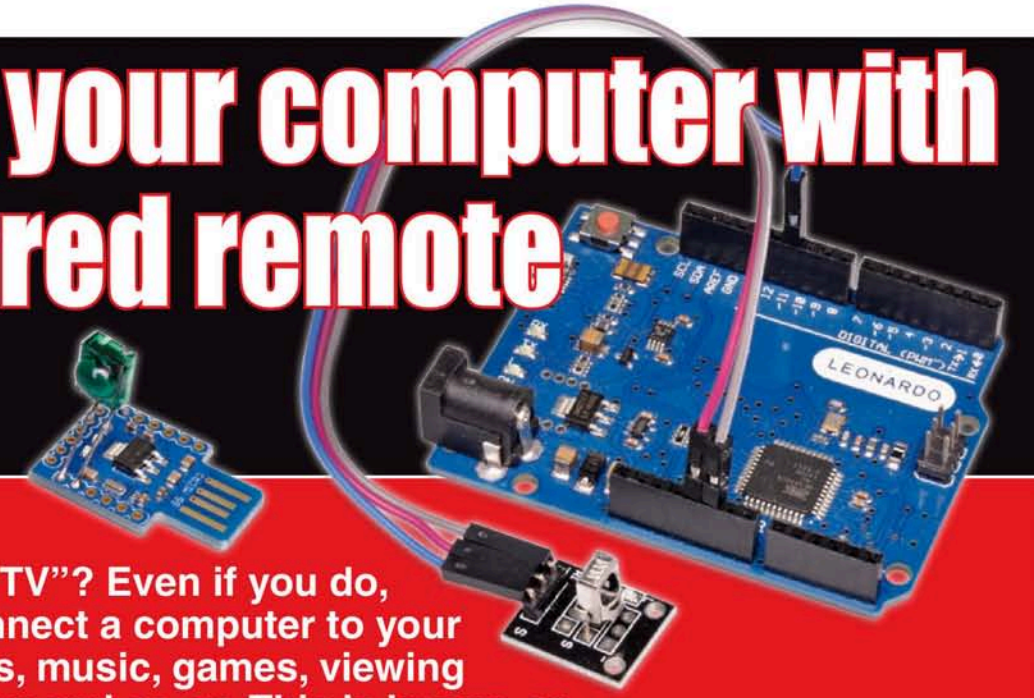
Control your computer with an infrared remote control



By Tim Blythman

Don't have a "Smart TV"? Even if you do, you may want to connect a computer to your TV for playing videos, music, games, viewing photos, web browsing and so on. This is known as a home theatre PC (HTPC). But operating a keyboard and mouse from the couch is clumsy. Why not use an infrared remote control for important functions like play, pause, next track, etc? It's surprisingly easy to do!

Like many tech-savvy people, I have a computer hooked up to my TV. I use it mainly for watching DVDs and YouTube videos on the big screen. I can even play games or surf the net.

But if I'm sitting back watching a movie and I want to pause it to get a drink, I don't want to fiddle around with a wireless mouse or keyboard.

I have trouble with my wireless mouse since its range is only just good enough to reach from the couch to the TV, so it doesn't work reliably. And I often forget to turn it off after using it, prematurely flattening its batteries.

An infrared remote control is far better suited to that sort of task and you probably already have one (or many!) at hand, which are likely to have some spare buttons which you could re-assign for various purposes. It's so much easier to just pick it up and press a button.

You may already have the parts needed to build this project. There's hardly any assembly required since it only involves two components. You can use it with a wide range of remote controls, including inexpensive generic programmable remotes.

You might own a HTPC, like the ASUS PB40, or have built your own to use with a TV. While useful, it can be a pain to control using traditional means. That's why we've come up with a way to use a standard IR remote to control it.

How does it work?

If you're familiar with the Arduino Leonardo's capabilities, you might have an inkling as to how we achieve the computer interface. The Leonardo has a USB interface and it can be set up to appear, from the computer's point of view, as a USB keyboard and/or mouse. This is also true of other ATmega32U4-based Arduino boards; there are a few.

So then we just need to arrange to receive infrared commands and we can translate them into keystrokes or mouse movements/clicks.

The Leonardo remains attached to the computer's USB port (you can even use it with a Raspberry Pi) so it doesn't need any external source of power.

The only difficulty is knowing what codes to expect from the remote control. For this, we can temporarily set up the Leonardo to tell us what codes it is receiving. We've already done this with a remote control that's available from Jaycar so you can simply use the codes we provide and get the remote control up and running in minutes.

It sounds simple, but the devil is in the detail. What keystrokes do we need to emulate? And how do we send them?

Hardware

As we mentioned, we can use pretty much any ATmega32U4-based Arduino

This remote control from Jaycar Electronics (XC3718) has 21 keys, each of which generates a different code based on the NEC IR protocol. These codes are detected and converted into keystrokes or mouse actions.

board, including the "Leonardo" or the smaller "Leostick" version that's available from Jaycar.

If space is at a premium, there is a variant known as a "Micro", and an even smaller (clone) version, which can be found under the name "Beetle". The Beetle isn't much bigger than most other USB dongles, so should fit just about anywhere.

A 3-pin IR receiver module can then be attached to the Arduino board, so we can now receive the signals from our remote control.

Software

Fortunately, there are a number of libraries available that already do most of the hard work for us. The first one (IRremote; github.com/z3t0/Arduino-IRremote) is used to receive and decode the infrared signals, giving us a different code for each button that's pressed on the remote control. This is a great library that can also be used to transmit infrared signals.

The two other libraries we're using allow us to emulate a keyboard (github.com/arduino-libraries/Keyboard) and a mouse (github.com/arduino-libraries/Mouse). The only remaining hard part is deciding which infrared code corresponds to which action.

With most of the complex function hidden in the libraries, our software sketch mainly deals with reading the codes from the infrared receiver library and then feeding the appropriate actions to the keyboard and mouse emulation libraries.

Construction

There isn't much to the hardware so it makes sense to assemble it first. The hardware can be used for figuring out what code is generated by each remote control button, and then re-used as the actual IR/keyboard/mouse interface. We built two prototypes using different Arduino modules as follows.

A tiny Beetle

The Arduino Beetle variant is a minimal ATmega32U4-based board designed by DFRobot. Although it hasn't been around for long, it has been "cloned" and these clones are available from many online stores. We don't even need to solder the supplied headers to it. We can simply solder the infrared receiver straight to the pads on the board.

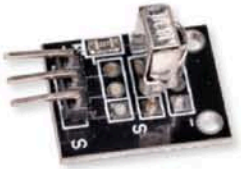
When complete, the final unit is smaller than most USB flash drives. The infrared receiver's GND pin is soldered to the GND pad on the PCB, the V_{CC} pin to the 5V pad and the DATA pin to digital input D11. The infrared receiver library can use any digital pin as the input but this is the one that we have chosen.

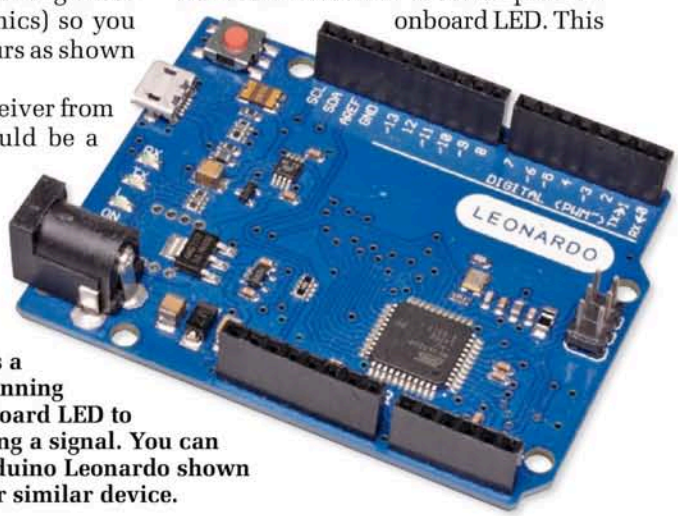
Most infrared receiver modules use the same pinout (including those sold by Jaycar and Altronics) so you can most likely solder yours as shown here.

But if you're using a receiver from a different source, it would be a good idea to double-check the data sheet. Looking at the lens from the front with the leads at the bottom, the pins from left-to-right are DATA, GND and V_{CC}.

If you like, you can carefully twist the receiver so that it will face the right way (towards the couch you are comfortably sitting on) when plugged into the computer. As long as the wires don't touch, you should have no troubles. Use heatshrink insulation if in doubt.

The Beetle can just be plugged into a USB type-A port on a computer, as is.





This IR receiver module is a great way to get up and running quickly. It also has an onboard LED to indicate when it is receiving a signal. You can then pair this with the Arduino Leonardo shown right, an Arduino Micro or similar device.

There are a few variants of Arduino compatible boards that will work with this project, like the ProMicro pictured. Compatible boards need to be based on the ATmega32U4 processor which has a built-in USB interface.

A larger variant

If you have an Arduino-compatible Leonardo or Micro board lying around for prototyping, it is entirely possible to put this project together without any soldering. Perhaps you just want to test out that it does what you want before assembling something more permanent.

In that case, we can use an Arduino-compatible module and some jumper leads to quickly put everything together. It may not be as compact but if your other family members don't mind bits of electronics sitting near the TV, it will work just as well as the Beetle version.

We also happened to have an infrared receiver assembly that includes the actual receiver module plus an onboard LED. This

B11

	A	B	C
1	CH-	0xFFA25D	
2	CH	0xFF629D	
3	CH+	0xFFE21	
4	PREV	0xFF22DD	
5	NEXT	0xFF02FD	
6	PLAY/PAUSE	0xFFC23D	
7	VOL-	0xFFE01F	
8	VOL+	0xFFA857	
9	EQ	0xFF906F	
10	0	0xFF6897	
11	100+		
12	200+		
13	1		

Finding out the codes that an IR remote control uses is as simple as opening a spreadsheet program and loading our "IR_Code_Typer.ino" sketch, which types the received codes directly into a spreadsheet.

means that you can easily see if it's receiving a signal or not.

If using such a module, check the markings on it to see which pins are which. They generally have an "S" to identify the data pin and a "-" for the ground pin, with the unmarked middle pin being positive 5V supply.

Run a jumper lead from the "S" pin to D11 on the Leonardo (we've used blue), "-" to GND (grey) and the middle pin to 5V (violet).

Getting the codes

If you aren't using the Jaycar remote control, you will need to figure out which codes are produced by each button that you intend to use. We've written a brief sketch which looks for signals from the infrared receiver and then types that code out on the PC using the emulated keyboard.

You can dump the codes into a spreadsheet or other document for use in our next step. Using a spreadsheet makes it easy to assign a name to each code for later reference.

Keep in mind that the buttons you use on the remote shouldn't be used for anything else, even if the TV is in a different mode.

Otherwise, the TV and computer might both respond to the same button press, with unexpected results.

Finding out which key codes to generate

Having determined what button you've pressed on the infrared remote, the Arduino code then needs to know which key or button press to generate in turn. This will depend on the software that you're running on the PC.

I use the VLC media player for watching videos on my HTPC. It's free and for the most part, it just works. If you use a different player, it will probably have a different set of keyboard shortcuts although most seem to use the space bar to play/pause. If in doubt, open your player of choice and mash away at the keyboard until you find out what key does what!

The commands that I wanted to use for VLC are: play/pause, toggle fullscreen mode, skip backwards and forwards. There's a great guide to all the shortcut keys at https://wiki.videolan.org/Hotkeys_table/

The keys I needed are in the first dozen listed, so this information was easy to establish.

The Jaycar remote control I used only has a single play/pause toggle button, so I had to settle for using the space key to toggle between play and pause. Toggling fullscreen involves simply pressing the "F" letter key.

For skipping forwards and backwards, we have the choice between very short, short, medium and long jumps.

According to the application's settings, a short jump is 10 seconds, which sounds like a good amount and is accessed using the Alt-Left Arrow or Alt-Right Arrow key combinations.

Sending keystrokes to a PC

The Arduino keyboard library is fairly easy to use. For example, to send the "F" keypress for toggling fullscreen mode, we can simply use this line of code:

```
Keyboard.write('f');
```

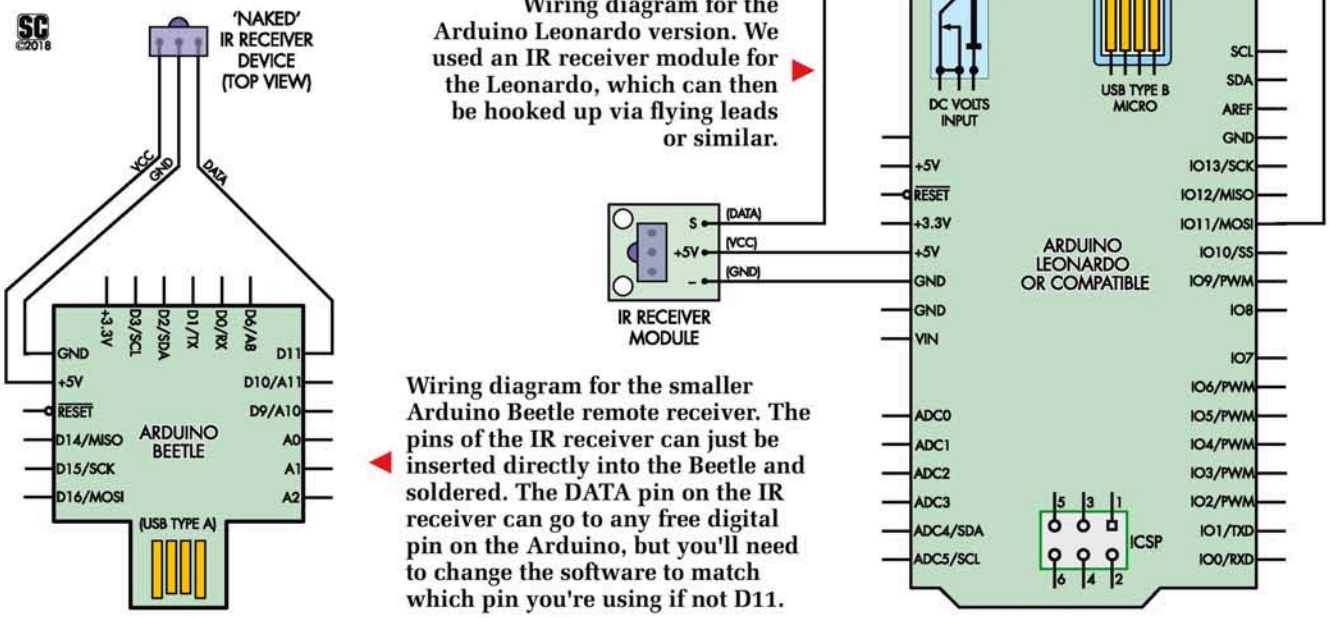
It's almost as though we are printing a character to the serial monitor. But for key combinations like Alt-Left Arrow, it's not quite so easy.

There are two catches here. One is that we are sending a non-printing key (ie, the arrow key) and the second is that we're sending a key modifier (Alt).

This web page gives an overview of all the special keys: www.arduino.cc/en/Reference/KeyboardModifiers

This tells us that to send a Left Arrow keypress, we can use the following code:

```
Keyboard.write(
  KEY_LEFT_ARROW);
```



Wiring diagram for the Arduino Leonardo version. We used an IR receiver module for the Leonardo, which can then be hooked up via flying leads or similar.

Wiring diagram for the smaller Arduino Beetle remote receiver. The pins of the IR receiver can just be inserted directly into the Beetle and soldered. The DATA pin on the IR receiver can go to any free digital pin on the Arduino, but you'll need to change the software to match which pin you're using if not D11.

To send Alt-Left Arrow, we need to send the computer the correct key presses and releases in the correct order, with a slight delay, as that is how the computer is expecting to receive them (as though a real human was pressing the keys):

```
Keyboard.press(KEY_LEFT_ALT);
Keyboard.press(
  KEY_LEFT_ARROW);
delay(100);
Keyboard.releaseAll();
```

This is a bit involved but it gives us a lot of flexibility. For example, you could use the following code sequence to run any Windows program (in this case Notepad) using the WIN+R shortcut:

```
Keyboard.press(KEY_LEFT_GUI);
Keyboard.press('r');
delay(100);
Keyboard.releaseAll();
delay(200);
Keyboard.print("notepad");
Keyboard.write(KEY_RETURN);
```

If you're going to use a sequence like this, it's a good idea to test it individually before mapping it to an infrared remote button and remember that the computer may respond differently if a different program has the focus (ie, is in the foreground) when the sequence is activated.

For sequences which start with a press of the "Windows Key", like the one immediately above, this should not be a problem as they are captured by the operating system, regardless of which program is in the foreground. But it it's also worth testing what happens if a certain keystroke occurs under a different program.

What about the mouse?

As we mentioned, there's also the possibility of emulating mouse movements and button presses. If you have a spare group of five or even nine buttons on the remote control, it's possible to use them to move the mouse cursor around and click.

The library provides two different functions to control the mouse. The simplest is:

```
Mouse.move(x,y);
```

This simply moves the mouse pointer in the x and y directions by the number of pixels specified. If x is negative, the pointer moves left and if x is positive, the pointer moves right. Up is negative on the y-axis. To simulate a left-click, you can use:

```
Mouse.click();
```

If you want to click a different button, do it like this:

```
Mouse.click(MOUSE_RIGHT);
```

Note that all mouse movements are relative. You can't send a command to move the pointer to a particular position on the screen. If you have to do this, you might be able to come up with a scheme where you move the mouse into one corner of the screen and then move it relative to that point, but we won't go into details as we haven't tried it.

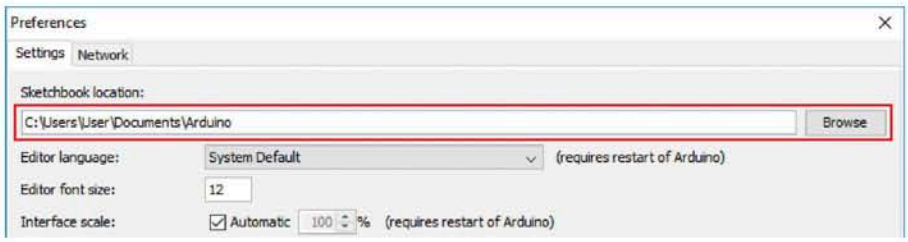
In practice, the best way to implement mouse cursor control with an infrared remote is to have a button each for up, down, left, right and click. Extra buttons, if available, can be used for diagonal movements.

This makes steering the pointer feel a bit like playing an old video game with a joystick but it is fine for some basic screen navigation, eg, to select a video to play.

```
IR_HID_XC3718

void loop() {
  decode_results  results;        //struct for results of IR rx
  static unsigned long lastcode=0;
  unsigned long code;
  if (irrecv.decode(&results)) {    //decode
    code=results.value;
    irrecv.resume();
    //Serial.println(code,HEX);
    if(code==0xFFFFFFFF){code=lastcode;}                    //emulate NEC repeat
    if(code==0xFF18E7){Mouse.move(0,-10);}                  //XC3718_2 (up)
    if(code==0xFF10EF){Mouse.move(-10,0);}                  //XC3718_4 (left)
    if(code==0xFF5AA5){Mouse.move(10,0);}                   //XC3718_6 (right)
    if(code==0xFF4AB5){Mouse.move(0,10);}                   //XC3718_8 (down)
    if(code==0xFF30CF){Mouse.move(-10,-10);}                //XC3718_1 (up left)
    if(code==0xFF7A85){Mouse.move(10,-10);}                 //XC3718_3 (up right)
    if(code==0xFF42BD){Mouse.move(-10,10);}                 //XC3718_7 (down left)
    if(code==0xFF52AD){Mouse.move(10,10);}                  //XC3718_9 (down right)
    if(code==0xFF38C7){Mouse.click(MOUSE_LEFT);code=0;}     //XC3718_5 (click), clear to
    if(code==0xFFC23D){Keyboard.write(' ');code=0;}         //XC3718_PLAYPAUSE, no repeat
    if(code==0xFF22DD){                                     //XC3718_PREV
      Keyboard.press(KEY_LEFT_ALT);
      Keyboard.press(KEY_LEFT_ARROW);
      delay(100);
```

By changing the value highlighted, we can change which infrared code/button press the Leonardo responds to. For this line of the sketch, if the current code matches, a signal is sent to the computer to move the mouse pointer ten pixels to the right.



To manually install the libraries (rather than using the library manager), unzip or copy them into the Arduino libraries folder. This can be found by going to the File → Preferences menu in the Arduino IDE and looking for the "Sketchbook location", as shown above. The libraries are stored in a subfolder at this location.

Getting the infrared codes

If you are using the suggested Jaycar remote control and already have the Arduino IDE installed, jump ahead to "Uploading the main sketch".

If you have an existing remote control you would like to make work, you will first need to upload the "IR_Code_Typer" sketch to find out what codes correspond to what keys.

To compile and upload the software that runs on the board, we need to have the Arduino IDE (Integrated Development Environment) installed.

This can be downloaded from www.arduino.cc/en/main/software for Windows, macOS and Linux.

Download and install a version to suit your operating system and start the Arduino IDE. You will need at least version 1.6.4 to use the Library Manager in the next step.

Open the Library Manager by going to the Sketch → Include Library → Manage Libraries menu and search for "irremote". When you find it, click on the install option that is presented.

If the Library Manager is not working or not available, you have the option of installing the IRremote.zip library supplied in our download package using the "Add .ZIP Library" option in that same menu.

Now plug the device into a USB port on the computer and select the board's serial port in the Tools → Port menu. Observe whether the board is seen as a "Leonardo" or "Micro" and based on this, select either "Arduino Leonardo" or "Arduino/Genuino Micro" under the Boards menu. If you choose the wrong option it simply won't work, so if in doubt try one or the other.

Before uploading the code, open a text editor such as Notepad or Leafpad, as the board becomes a keyboard device immediately after the upload completes.

Now open the IR_Code_Typer.ino sketch file, which you will have extracted from our download package, then click "Upload" (or press CTRL+U on your keyboard).

Assuming the upload completes successfully, switch to the text editor that you opened earlier, then point your infrared remote control at the unit and press one of the buttons.

You should see a hexadecimal value appear and pressing a different button should give you a different code. You may also get different codes if you hold the button down.

A good way to record the codes is to open a spreadsheet program and create a list with the button names that you want to use in the first column.

Then move the cursor to the top of the second column and press each remote control button in turn, corresponding to the names in the first column.

The code should appear in that cell and the cursor will move to the next cell below.

Uploading the main sketch

You might like to try uploading the sketch to the board without making any changes, just to check that everything works as it should.

The sketch code we have created will work with the Jaycar XC3718 remote control pictured earlier, but can be supplemented with your own codes.

By default, it uses the numbers 1-9 as a joystick type interface, with the 5 key being the same as a left mouse click and the other numbers moving the pointer in different directions by 10 pixels at a time.

For example, number 4 is to the left of centre so it will move the mouse to the left.

We've also set up the Play/Pause button to emulate a spacebar press and the Previous and Next buttons generate Alt-Left and Alt-Right keypresses respectively. These last two correspond to forward and back on many web browsers too.

If you are using a different remote control or want to change what the buttons do, you will need to modify the code. Specifically, you will be modifying the series of "if" statements which check to see which IR code has been received and then perform an appropriate action.

Before making any modifications, save the Sketch file under a different name so that you don't overwrite the original.

Using your spreadsheet as a reference, replace the hexadecimal value in each "if" statement with one of the button codes that you noted earlier. Then, inside the braces that follow that if statement, you will need to change or add the code to send the necessary keyboard or mouse events to the computer.

For example, let's say that in response to button code 0xFF1234 being received, you want to generate a keypress equivalent to pressing CTRL+ALT+t on the keyboard. Your new "if" statement would look like:

```
if (code == 0xFF1234) {
  Keyboard.press(
   KEY_LEFT_CTRL);
  Keyboard.press(KEY_LEFT_ALT);
  Keyboard.press('t');
  delay(100);
  Keyboard.releaseAll();
  code=0;
}
```

The "code=0;" line towards the end should be included if you do not want the action to be repeated if the key is held down. If you do want it to repeat, leave that bit out.

Once you have done this with all the buttons you want to use on the remote and removed any extraneous "if" statements which may be left over from the original code, you can proceed to upload this sketch to the main board.

You can handle codes from multiple remote controls in the same sketch.

Having uploaded the sketch, check that it works as expected. If you find any keys are not responding or not doing what you think they should, check the code in the "if" statements.

Finalising the code

You might notice in the codes that we check for 0xFFFFFFFF. This is a code emitted by remote controls that use the NEC encoding which indicates that the current key is being held down and the effect of that key should be repeated.

We implement this by saving the code of whatever key was last pressed and then substituting that code if a repeat code is seen.

What next?

It's a very useful device as described, but these Arduino boards have a number of spare pins and you could use these for other tasks that can also be controlled by the remote control.

For example, you could wire up some LEDs and arrange for remote buttons to switch them on and off for some instant mood lighting.

You could even consider integrating some code to switch remote power points on and off. You could do this using some Arduino code provided by Jaycar which works with the wireless power point switches. This can be downloaded from www.jaycar.com.au/iot-wireless-switch SC

Parts List

1 infrared remote control (eg, Jaycar XC3718)
1 infrared receiver module (eg, Jaycar ZD1952, Altronics Z1611A)

Beetle-based version
1 DFRobot Beetle or equivalent (ProMicro etc)

Leonardo-based version
Arduino Leonardo board or equivalent (eg, Jaycar XC4430, Altronics Z6214)
1 set of plug-socket breadboard leads (eg, Jaycar WC6028, Altronics P1017)

PRODUCT SHOWCASE

New Hakko Soldering Products at Electronex Australia

HK Wentworth, sole authorised wholesale distributor for Hakko soldering solutions in Australia, will be showcasing new Hakko products alongside their Electrolube electro-chemical solutions at Electronex Australia (Rosehill Gardens, Sydney) next month.

Experts from both Hakko and Electrolube will be available on Stand A16 to assist with customer application queries.

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Calibration is not required – just power up and the system is ready for use. A boost control delivers an injection of extra power to the soldering iron tip when required. while a tip sleep function reduces the tip temperature to preserve its life and reduce oxidization when the iron is not in use. There is also an activity monitor that provides cumulative data on tip heater loads and tip running time to aid in process control and manage operating costs.

Contact:
HK Wentworth
3/98 Old Pittwater Road, Brookvale NSW 2100
Tel: (02) 9938 1566
Website: www.electrolube.com.au

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2016 Electronex Sydney attracted over 1200 electronics design professionals, including electronic and electrical engineers, technicians and management, along with IT and communications professionals, defence, government and service techs.

For further information, contact:
Noel Gray, Australasian Exhibitions and Events Pty Ltd Tel: 03 96762133
Email: ngray@auexhibitions.com.au

Secured IoT endpoints with 32-bit MCU featuring chip-level security

With the tremendous growth of IoT nodes, security has become an afterthought for many designers, increasing the risk of exposing intellectual property (IP) and sensitive information.

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These MCUs, based on the Arm Cortex-M23 core, feature chip-level tamper resistance, secure boot and secure key storage that, when combined with TrustZone technology, protect customer applications from both remote and physical attacks.

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Both MCU families offer Microchip's latest generation Peripheral Touch Controller (PTC) for capacitive touch capability with best-in-class water tolerance and noise immunity, making the devices ideal for a myriad of automotive, appliance, medical and consumer Human Machine Interface (HMI) applications.

In addition, they provide industry-leading power consumption in active and all sleep modes with Microchip's proprietary picoPower technology.

The SAM L10 received a ULPMark score of 405, which is over 200% better performance than nearest competitor certified by EEMBC.

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Contact:
Microchip Technology Australia
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Tel: (02) 9868 6733
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(SC Jan-May '17) This completely new amp design incorporates most of the features of Silicon Chip Ultra-LD Mk4 200W amp but uses easy-to-solder through-hole components - no SMD! 200W into 4Ω load. Heatsink for illustration purposes, H 0536 $25.95.

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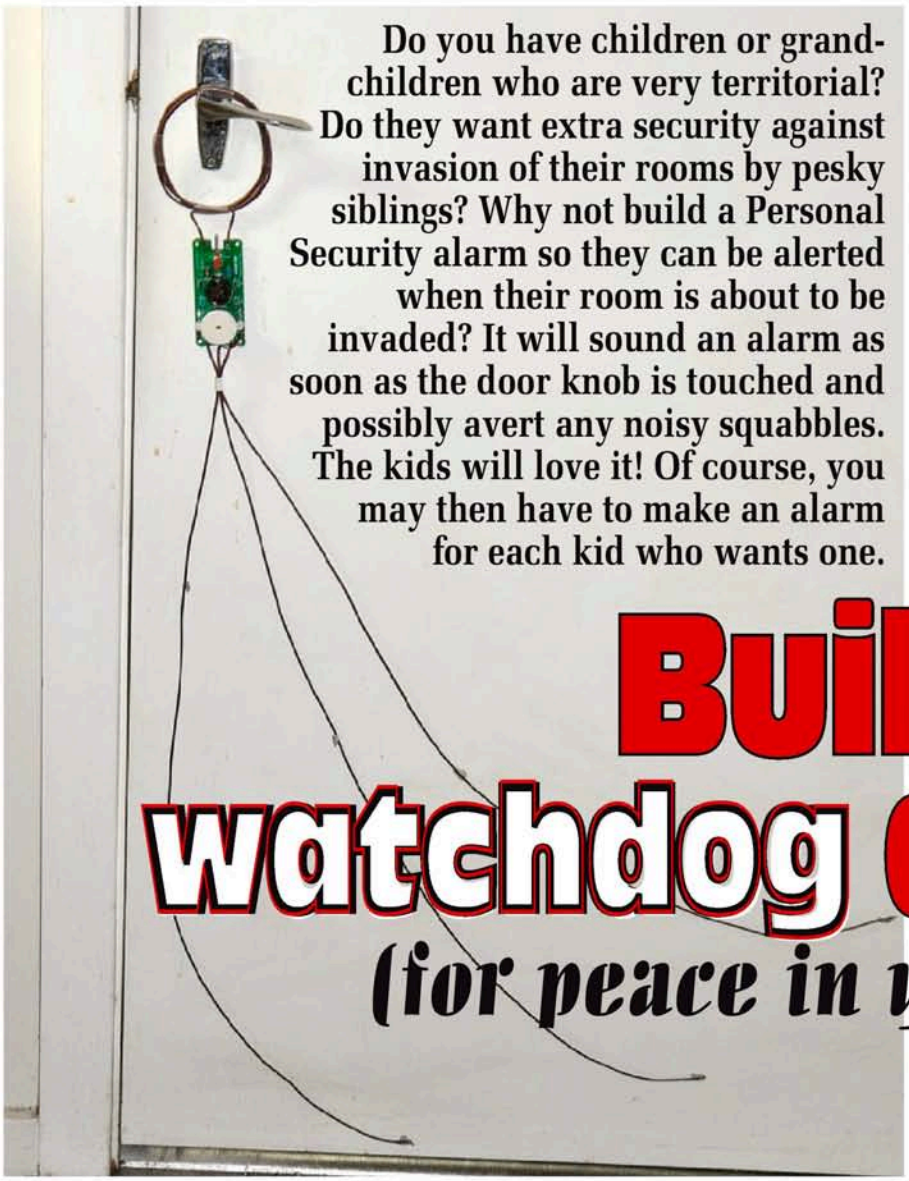
M-u-u-u-m . . . he's been in my room again!



Do you have children or grandchildren who are very territorial? Do they want extra security against invasion of their rooms by pesky siblings? Why not build a Personal Security alarm so they can be alerted when their room is about to be invaded? It will sound an alarm as soon as the door knob is touched and possibly avert any noisy squabbles. The kids will love it! Of course, you may then have to make an alarm for each kid who wants one.

Build the watchdog alarm

(for peace in your home!)

By JOHN CLARKE

A kid's domain is sacrosanct – especially if they are fortunate enough to have their own room. But no amount of threats or retribution will keep a sibling (or parent!) out when they're uninvited! Kids are sneaky that way. . .

This Watchdog Alarm is effective and certainly preferable to more drastic measures such as trip wires, buckets precariously balanced above doorways, trapdoors, Gatling guns and other schemes which war-like adolescent humans are likely to dream up to protect their room, cave, cubby house or lair.

Having an audible warning means the hostile room occupant will immediately be alerted to an undesirable alien (eg, little brother!) touching the doorknob, even before they open the door.

That warning may or may not be sufficient to prevent the mischief maker from creating mayhem by opening the door, knowing they have been detected, but it will certainly be a deterrent against further incursions.

(OK, we're not seriously suggesting this alarm as a proper security device . . . but it could have other applications where a change in the capacitance of a metal object needs to be detected.)

The idea for this project came from an article in the April 1981 edition of Electronics Australia for a portable burglar alarm.

Powered from a 9V battery, it used a hex Schmitt trigger connected as a couple of oscillators and a timing circuit to drive a siren whenever the doorknob was touched.

That article suggested it as being suitable for use in hotel rooms but that is not practical today for modern hotel and motel rooms, which are usually entered by swiping a card through a magnetic scanner, or even via an RFID tag.

Nevertheless, with child territoriality in mind,

we have updated this concept using a low power microcontroller. The resulting Watchdog Alarm uses an 8-pin micro on a small PCB which can be easily assembled and set up within an hour. It is powered from a small, onboard 3V cell and is presented as a bare printed circuit board (PCB) assembly to minimise cost.

A sensor loop is placed over the doorknob (no electrical connection required) to detect when this is touched. The Watchdog Alarm is turned on and off with a toggle switch and an indicator LED flashes to show that the doorknob is being monitored.

When the Watchdog Alarm is first switched on, the indicator LED flashes rapidly for about 10 seconds during which time the doorknob can be touched without sounding the alarm.

Touching the doorknob during this period will cause the LED to light fully. You can use the 10-second period to check the operation of the Watchdog Alarm. We'll explain this later in the setup section.

Once the 10-second period has expired, the LED will flash about once per second to indicate that the Watchdog Alarm is armed. Touching the doorknob then will cause the alarm to sound.

There are two alarm options. One is a on-board piezo transducer that beeps twice every three seconds (about 1.5Hz) if the alarm is triggered.

For a much louder alarm you can use an off-board piezo siren. This is more likely to wake more comatose room occupants (no guarantees, though!).

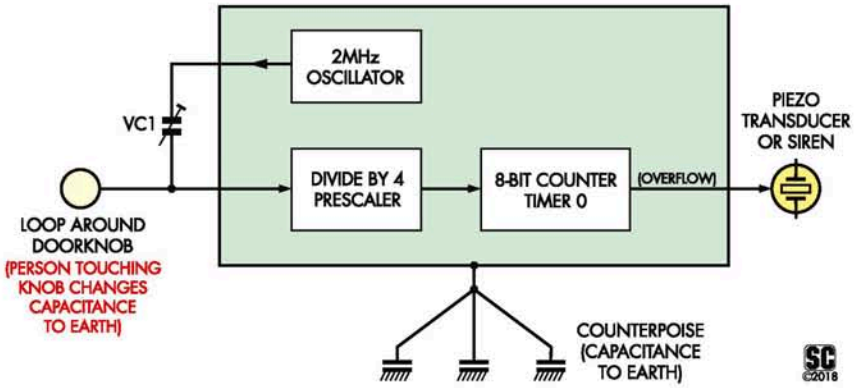


Fig.1: the Watchdog's microcontroller feeds a 2MHz signal via trimmer capacitor VC1 to the doorknob sensor loop. If someone touches the doorknob, their body capacitance shunts this signal to ground. The micro senses this and sounds the piezo alarm or siren.

Features

- Detects the presence of a hand on a doorknob
- Option of piezo transducer or louder siren for alarm
- Testing period during initial power on without sounding alarm
- LED indicator shows initial test period, normal monitoring and alarm

Block & circuit diagrams

Fig.1 shows the block diagram. As already noted, this alarm uses a microcontroller and it produces a 2MHz signal which is applied to the doorknob which is monitored at the same time.

If a pesky human touches the doorknob, the person's body capacitance will effectively shunt away the 2MHz signal and this will cause the micro to sound the alarm. The circuit requires a "counterpoise", made from three lengths of wire and this serves to provide a virtual ground reference.

The circuit, shown in Fig.2, is based on a PIC12F617 8-pin microcontroller (IC1).

Switch S1 connects the 3V button cell and diode D1 provides reverse polarity protection. If the cell is somehow

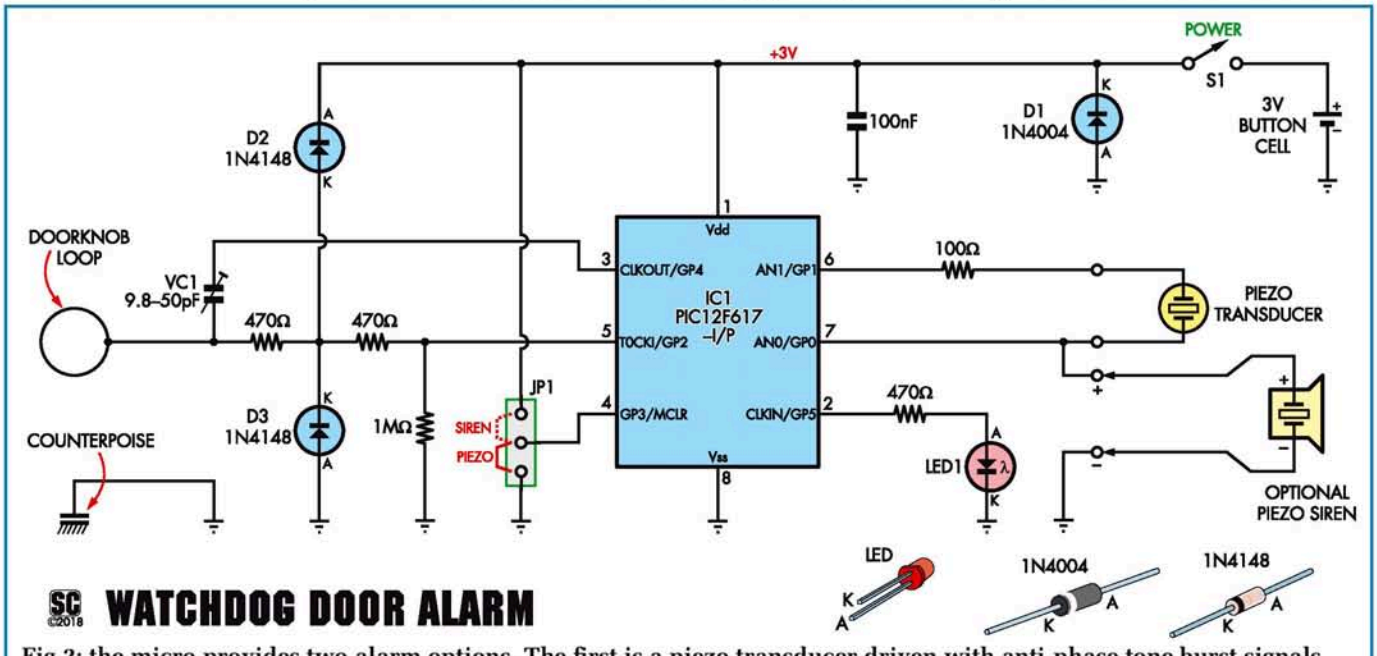


Fig.2: the micro provides two alarm options. The first is a piezo transducer driven with anti-phase tone burst signals which effectively doubles the single pin output voltage. The second is a lounder off-board piezo siren which has its own internal oscillator. LED1 shows the alarm status.

The two "sirens" applicable, shown here not far off life size. On the left is the louder of the two which must be mounted off the PCB. At right, the piezo transducer, can be mounted directly on the PCB.

inserted incorrectly, the diode will conduct and safely limit the reverse voltage to IC1 at around -0.6V. Admittedly, the cell holder we use makes it rather difficult (if not impossible!) to allow the cell to be inserted incorrectly, so that is an added prevention.

IC1 uses an internal 8MHz oscillator and this is divided by four to provide a clock signal of 2MHz at pin 3, CLKOUT.

Most of the time IC1 is in sleep mode and its internal 8MHz oscillator is stopped. It is woken once a second by its internal watchdog timer (yep, that's where we got the name from!) to flash the red indicator LED and check if the doorknob is being touched. Sleep mode reduces the current consumption of IC1 down to a very low level in order to maximise the life of the cell.

In more detail, the internal watchdog timer runs continuously and once a second it wakes up IC1. The 8MHz oscillator then starts, the program in IC1 runs and the CLKOUT output at pin 3 then produces the 2MHz signal. This signal is applied via an adjustable trimmer capacitor, VC1, to the T0CKI (pin 5) via 470Ω resistors. The wire loop for the doorknob sensing is attached to the trimmer capacitor at the opposite side to CLKOUT.

If the doorknob is not touched, the input to IC1 at T0CKI will receive the 2MHz signal passing through the trimmer capacitor.

The block diagram of Fig.1 depicts what happens inside IC1. The 2MHz signal is applied to a divide-by-four prescaler and then to an 8-bit counter (TIMER0). At 2MHz, the output from the prescaler is 500kHz (2MHz/4). TIMER0 counts at the 500kHz rate and the overflow output (T0IF) goes high after 256 counts – the full count of the 8-bit counter.

TIMER 0 reaches the full count in 512µs. If its output does not go high after this period, then the software assumes there is no signal. Lack of signal would mean that the 2MHz signal is being diverted to ground by flow through the doorknob by body capacitance.

Several extra parts are used between the VC1 output and the T0CKI input. This includes the 470Ω resistors and diodes D2 & D3 which are included to protect the pin 5 input. Should the person have a static charge before touching the doorknob, diodes D2 or D3 will clamp the voltage to the positive or 0V supply depending on the static voltage polarity. The 470Ω resistor to D2 and D3 limits current. The next 470Ω resistor to pin 5 protects the internal protection diodes of IC1.

The 1MΩ resistor is there to pull pin 5 to 0V so the input does not float at a voltage between 0V and the supply. Additionally, during sleep, the pin 5 input is changed from an input to a low output, further ensuring the input is not floating. A floating input will cause IC1 to draw extra current.

Piezo drive

The GP3 input, pin 4, connects to the 3-pin header JP1. The position of a 2-pin jumper on this header selects whether you use the lower-cost on-board piezo transducer or the louder off-board piezo siren. The selector is necessary because each is driven differently. The piezo transducer is driven by a burst signal generated by the micro, while the piezo siren has its own internal constant tone generator and is turned on when pin 7 goes high, feeding it with 3V DC.

When set in the piezo position, GP3 is tied low and if

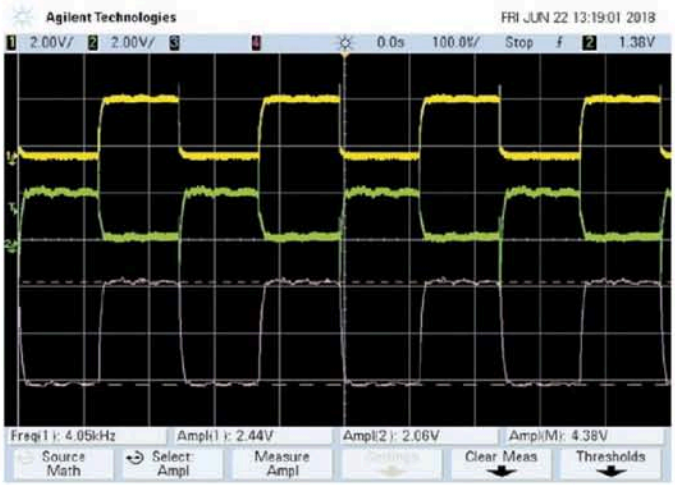


Fig.3: the complementary (anti-phase) drive signals applied to the piezo transducer, from pins 6 & 7. The two signals are at 4.05kHz and have an amplitude very close to 2.06V and 2.44V peak-to-peak, not allowing for the overshoot spikes. Therefore the total signal applied to the transducer will be close to the sum of those voltages 4.5V peak-to-peak, as shown in the purple mathematical trace.

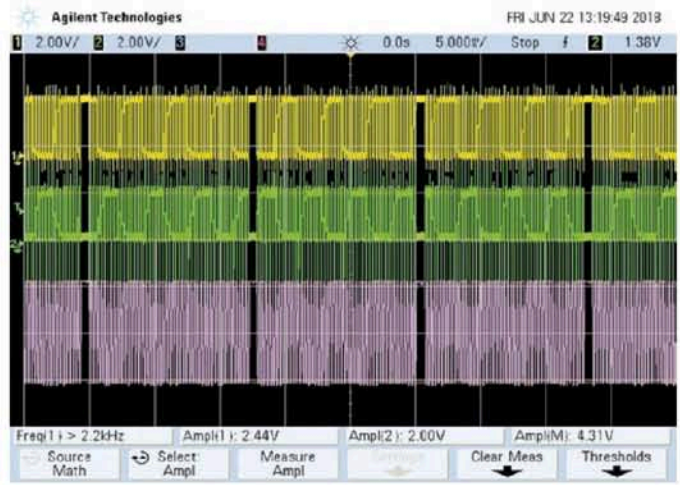


Fig.4 shows the same complementary drive signals fed to the transducer as in Fig. 3 but at a slower sweep speed of 5ms/div. This shows how the signal bursts are rapidly chopped to give it a burbling sound, which is more attention-getting. Note that we are running the piezo transducer at close to its resonant frequency to maximise its audible effect.

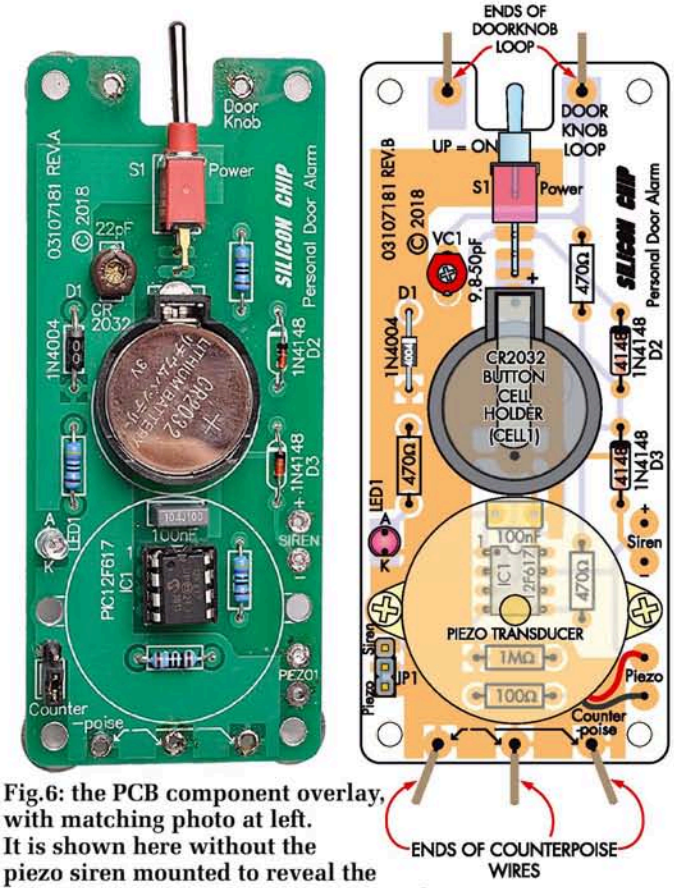


Fig.6: the PCB component overlay, with matching photo at left. It is shown here without the piezo siren mounted to reveal the PIC and other components underneath.

the doorknob is touched to trigger the alarm, the piezo transducer sounds, as pins 6 & 7 (GP1 & GP0) alternately go high and low, to deliver bursts of 4kHz signal. In a small room and at close quarters, this can be quite loud.

Certainly, there is no mistaking that the miscreant has been "pinged". The alarm will sound while ever the doorknob is touched. As soon as the doorknob is released, the alarm will stop.

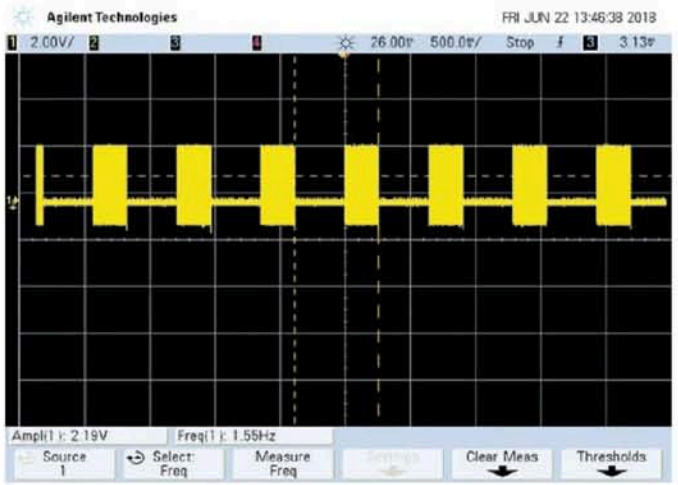


Fig.5: the piezo transducer signal from pin 7 of IC1,at the very low sweep speed of 500ms/div and this illustrates the 260ms duration and 1.55Hz frequency of the burbled tone bursts from the microcontroller. The burbling of the tone bursts makes the sound seem much louder.

Specifications

Supply voltage: 3V lithium cell which operates down to 2V

Current drain: 5.4µA at 2V; 7.5µA at 3V,with LED flashing once per second
(Piezo siren; when sounding add an extra 250µA)

Expected cell life: ~1 year continuous use

Indicator flash: 3.2ms once each 1.152s, constantly lit during detection

Testing period indication: LED flashes 3.5 times per second during first 10 seconds after power up. Fully lit during detection

Alarm response time: 0.5s (285ms during 10 second testing period)

Piezo Transducer: 200ms bursts of 4.05kHz warbled at between 400Hz and 600Hz at a 1.55Hz rate

Piezo siren alarm: Uses intermittent siren or siren burst

The scope screen grabs of Fig. 3 & 4 show the complementary drive signals applied to the piezo transducer, from pins 6 & 7. In Fig.4, the two signals are at 4.05kHz and have an amplitude very close to 2.06V and 2.44V peak-to-peak, not allowing for the overshoot spikes. Therefore the total signal applied to the transducer will be close to the sum of those voltages÷ 4.5V peak-to-peak, as shown in the purple mathematical trace of Fig.3.

By the way, the reason the signals on both sides are the transducer are not identical is explained by the presence of the series 100Ω current-limiting resistor from pin 6. Note that we are running the piezo transducer at close to its resonant frequency to maximise its audible effect.

Fig.4 shows the same complementary drive signals but at a slower sweep speed of 5ms/div. This shows how the signal bursts are rapidly chopped which gives it a burbling sound which is more attention-getting.

Finally, Fig.5 shows the same signal at the very low sweep speed of 500ms/div and this shows the 260ms duration and 1.55Hz frequency of burbled tone bursts from the transducer.

When the JP1 jumper is in the siren position, the siren is powered by a high level (ie, the V_{CC} supply voltage) at the GP0 output with its other terminal connected permanently to ground.

Construction

The Watchdog Alarm is constructed on a PCB coded 03107181, and measuring 42 x 93mm. It is presented as a bare PCB that can be hung on the doorknob.

Fig.6 shows the PCB overlay. Begin construction by installing the resistors. There are only three values and of these, the only ones you could mix up are the 100Ω (brown black brown brown) and the 1MΩ (brown black green brown) in four-band code. Use a multimeter to check the value of each before inserting into the PCB. The three 470Ω resistors have yellow, purple, brown, brown coding.

Diodes D1 to D3 can now be installed taking care to orient correctly and noting that D1 is the 1N4004 and the remaining diodes are 1N4148s. The 100nF capacitor can be fitted now, followed by the IC socket (for IC1). It must

Parts list – Watchdog Door Alarm

1 double-sided PCB, coded 03107181, 42 x 93mm
1 SPDT PCB toggle switch (S1) [Altronics S1421]
1 20mm PCB button cell holder [Jaycar PH-9238, Altronics S5056]
1 CR2032 lithium cell
1 8-pin DIL IC socket
1 piezo transducer [Jaycar AB-3440, Altronics S6140] ***OR***
11-13V pulsating piezo siren [Jaycar AB3456, Altronics S6117]
1 3-pin header with 2.54mm spacing (JP1)
1 jumper shunt (JP1)
2 PC stakes (optional)
2 M3 tapped x 9mm spacers
4 M3 x 6mm screws (at least two polycarbonate or Nylon)
1 4m length of multistrand insulated wire (eg 24 x 0.2mm)
1 150mm length of 6mm diameter heatshrink tubing
4 10mm diameter self-adhesive surface savers (stick-on feet)

Semiconductors
1 PIC12F617-I/P microcontroller programmed with 0310718A.hex (IC1)
1 1N4004 1A diode (D1)
2 1N4148 diodes (D2,D3)
1 3mm red high brightness LED (LED1)

Capacitors
1 100nF 63V or 100V MKT polyester (Code 104 or 100n)
1 9.8-60pF trimmer capacitor (VC1)

Resistors (0.25W 1%)
1 1MΩ (Code brown black green brown or brown black black yellow brown)
3 470Ω (Code yellow purple brown brown or yellow purple black black brown)
1 100Ω (Code brown black brown brown or brown black black black brown)

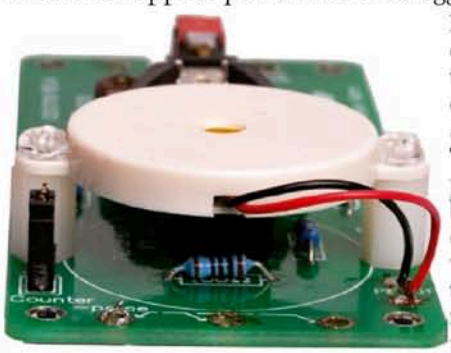
be oriented with the notch facing the 100nF capacitor.

The 3-way pin header for JP1 is next. Optional PC stakes are installed at the wiring points for the piezo transducer or for the siren (the wires could instead be directly soldered to the relevant pads).

Make sure the plus terminal of the button cell holder is oriented toward IC1 on the PCB. LED1 is mounted raised off the PCB (we made ours about 10mm high but it can be mounted higher). Take care with orientation – the longer (anode) lead goes to the hole marked with the 'A'.

VC1 can be installed either way around on the PCB.

Switch S1 is inserted into position and soldered in place. The switch applies power when the toggle is up. The toggle is protected inside the PCB cut out so is less likely to be inadvertently moved.



Here's how the on-board piezo transducer mounts on stand-offs above the PIC. The larger, more powerful siren can be mounted some distance away. It would connect to the "siren" pads, not the "piezo" pads as seen here.

You're likely to see this warning when programming the PIC12F617-I/P On the PICkit 3 it can be safely ignored, but other programmers may not support this programming.

Leave the siren or piezo transducer off for the moment.

Programming the microcontroller

If you purchase your PIC12F617-I/P microcontroller from the SILICON CHIP Online Shop (and tell us which project it's for!) it will come already programmed (there is no extra charge for programming).

However, if you want to program the PIC yourself, the file 0310718A.hex can be downloaded from the SILICON CHIP website.

There is one caveat: we are not using pin 4 of IC1 as the master clear ($\overline{MCLR}$) input but as an input for JP1. For master clear we use the internal $\overline{MCLR}$ instead. Some programmers will not support programming when the internal MCLR and internal oscillator are selected. If you are using a PICkit 3, the warning can be ignored and programming continued.

Make sure IC1 is oriented correctly before inserting into its socket (the notch on the IC matches the notch on the socket).

Now install the CR2032 cell in its holder and place a jumper link onto the 3-way header at JP1. Switch on S1 and if all is well, the LED will light or flash rapidly to acknowledge power has been connected.

All that's left now is to fit the piezo transducer or the off-board siren.

If you choose the piezo transducer, it is mounted to the PCB on 9mm spacers using 15mm M3 screws. It sits up 10mm above the PCB surface as there are other components (including IC1) underneath. The two flanges on the transducer housing will need the holes drilled out to 3mm.

There's a little wrinkle here: the piezo housing flanges do not *quite* allow for M3 screw heads, as the heads foul the circular side of the transducer. With our prototype, the sides of the heads were filed down for each screw that secures the piezo transducer.

Plastic polycarbonate or Nylon screws are easier to file down than steel. To secure the two screws, the standoff is rotated onto the screw thread instead of rotating the screw.

Then the Piezo and standoffs can be secured to the PCB with the screws on the underside of the PCB.

If you choose the significantly louder off-board siren, note that it is polarised – the negative (usually black) wire goes to the – siren terminal while the "pulse" wire (usually yellow) goes to the + siren terminal. The red wire is not used for three-wire sirens. By extending the siren's black

The lip on the piezo transducer doesn't quite allow the screw heads to fit, so we filed off one edge before mounting. We used Nylon screws because they're a lot easier to file than normal screws!

Here's the door handle loop before heatshrinking and soldering in place. It consists of four turns of hookup wire, 90mm in diameter. The heatshrink helps hold its shape.

and yellow wires with suitable hookup or thin figure-8 wire, you can locate it some distance away from the PCB – even a few metres or so, if you wish.

Finally, don't forget to install the jumper shunt at JP1 in the correct position for the piezo transducer or siren whichever is used (the PCB is clearly marked).

Wiring

The loops for the door handle are made up using a 1.2m length of insulated wire to make four turns at 90mm in diameter. We fed our loops through lengths of 6mm diameter heatshrink tubing so that the loops would stay in place without unravelling. Strip back the two wire ends a few millimetres and solder the ends into the doorknob holes on the PCB.

For the counterpoise, cut three 900mm lengths of insulated wire, strip insulation from one end of each and solder to the counterpoise holes located at the bottom of the PCB. In use, these are spread out over the door and fixed using Blu-Tack or tape.

It makes sense, if possible, to use wires the same colour (or close) as the door to make them unobtrusive.

If you are placing this on a door that is not your own, then check to see if the mounting method does not stain or leave a mark on the door. In some cases, just having the three wires loosely dangling straight down will be sufficient.

Testing

Note that the Watchdog Alarm will not work if the door is metal-sheathed or if the door jamb is metal. It works best with timber-framed and timber doors with metal doorknobs. There is no need for an electrical connection from the doorknob to the wire loop, so the doorknob can be lacquered (such as coated gold or brass finishes) or exposed metal (such as brushed aluminium).

The three counterpoise wires can, like the doorknob loop, be made from any surplus hookup wire. They should be about 900mm long each – but can be a little shorter if your door handle is lower than standard. They solder to the PCB but don't connect to anything else. The short length of heatshrink tubing provides strain relief to the solder joints on the PCB.

And here it is shrunk and soldered. The loop simply drops over the door handle – no electrical connection is required as it detects capacitance – in this case, the capacitance of the person touching the doorknob on the other side of the door. When they do so . . . GOTCHA!

Place the wire loop over a doorknob and switch on. Adjust VC1 so that the LED flashes with the door handle untouched but lights up when touched. This is a trial and error adjustment, so try various settings of VC1. Once you find a good position where the hand is detected readily, the adjustment should not need changing again.

Note that for the first 10s after power is switched on, the LED will flash at a fast rate before flashing about once per second. That is if it is not detecting a touched door knob and the adjustment of VC1 is correct.

The period when the LED is flashing at the faster rate indicates that the piezo or siren, when connected, will not sound when the doorknob is touched until the 10 seconds has expired.

This is to allow the testing of the Personal Door Alarm when first switched on without causing a lot of noise from the alarm.

If you wish, stick some self-adhesive surface savers (hemi-spherical adhesive buttons) to the corners of the PCB to protect against scratching the door. SC

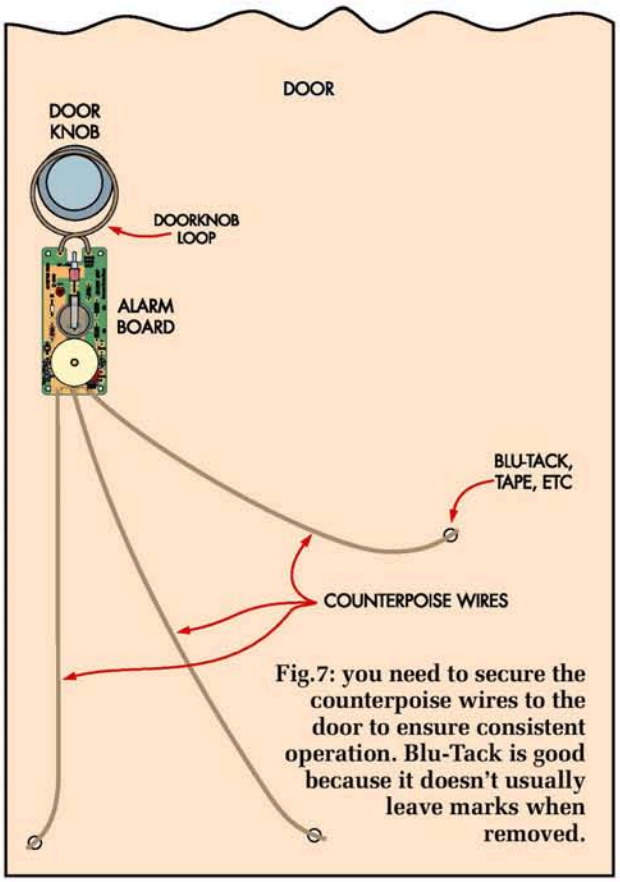


Fig.7: you need to secure the counterpoise wires to the door to ensure consistent operation. Blu-Tack is good because it doesn't usually leave marks when removed.

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PIC12F675-E/P	Courtesy LED Light Delay for Cars (Oct14), Fan Speed Controller (Jan18)
PIC16F1455-I/P	Microbridge (May17), USB Flexitimer (June18)
PIC16F1507-I/P	Wideband Oxygen Sensor (Jun-Jul12)
PIC16F88-E/P	Hi Energy Ignition (Nov/Dec12), Speedo Corrector (Sept13) Auto Headlight Controller (Oct13), 10A 230V Motor Speed Controller (Feb14) Automotive Sensor Modifier (Dec16)
PIC16F88-I/P	Projector Speed (Apr11), Vox (Jun11), Ultrasonic Water Tank Level (Sep11) Quizzical (Oct11), Ultra LD Preamp (Nov11), 10-Channel Remote Control Receiver (Jun13), Revised 10-Channel Remote Control Receiver (Jul13) Nicad/NiMH Burp Charger (Mar14), Remote Mains Timer (Nov14) Driveway Monitor Transmitter (July15), Fingerprint Scanner (Nov15) MPPT Lighting Charge Controller (Feb16), 50/60Hz Turntable Driver (May16) Cyclic Pump Timer (Sep16), 60V 40A DC Motor Speed Controller (Jan17) Pool Lap Counter (Mar17), Rapidbrake (Jul17), Deluxe Frequency Switch (May18)
PIC16LF88-I/P	Garbage Reminder (Jan13), Bellbird (Dec13), GPS Analog Clock Driver (Feb17)
PIC16LF88-I/SO	LED Ladybird (Apr13)
PIC16LF1709-I/SO	Battery Cell Balancer (Mar16)

$15 MICROS

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PIC16F2550-I/SP	Batt Capacity Meter (Jun09), Intelligent Fan Controller (Jul10)
PIC18F4550-I/P	Multi-Purpose Car Scrolling Display (Dec08), GPS Car Computer (Jan10)
PIC32MM0256GPM028-I/SS	Super Digital Sound Effects (Aug18)
PIC32MX170F256B-50I/SP	GPS Tracker (Nov13), Micromite ASCII Video Terminal (Jul14) Micromite Mk2 (Jan15) + 47µF, Low Frequency Distortion Analyser (Apr15) Micromite LCD BackPack [either version] (Feb16), GPS Boat Computer (Apr16) Micromite Super Clock (Jul16), Touchscreen Voltage/Current Ref (Oct-Dec16) Micromite LCD BackPack V2 (May17), Deluxe eFuse (Aug17) Micromite DDS for IF Alignment (Sept17), Tariff Clock (Jul18)
PIC32MX170F256D-501P/T	44-pin Micromite Mk2

$20 MICROS

PIC32MX470F512H-I/PT	Stereo Audio Delay/DSP (Nov13), Stereo Echo/Reverb (Feb 14) Digital Effects Unit (Oct14)
PIC32MX695F512H-80I/PF	Maximite (Mar11), miniMaximite (Nov11), Colour Maximite (Sept/Oct12) Touchscreen Audio Recorder (Jun/Jul 14)
PIC32MX470F512H-120/PT	Micromite PLUS Explore 64 (Aug 16), Micromite Plus LCD BackPack (Nov16)
PIC32MX470F512L-120/PT	Micromite PLUS Explore 100 (Sep-Oct16)
dsPIC33FJ64MC802-E/SP	Induction Motor Speed Controller (revised) (Aug13)
dsPIC33FJ128GP802-I/SP	Digital Audio Signal Generator (Mar-May10), Digital Lighting Cont. (Oct-Dec10) SportSync (May11), Digital Audio Delay (Dec11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12)

When ordering, be sure to select BOTH the micro required AND the project for which it must be programmed.

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Micromite 2.8-inch LCD BackPack kit programmed for the Altimeter project **$65.00**
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Elecrow 1A/500mA Li-ion/LiPo charger board (**optional**, Cat SC4308) **$15.00**

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PCB plus all on-board parts including programmed microcontroller (SMD ceramics for 10µF) **$20.00**

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MICROMITE LCD BACKPACK V2 – COMPLETE KIT (CAT SC4237) *(MAY 17)*
includes PCB, programmed micro, touchscreen LCD, laser-cut UB3 lid, mounting hardware, SMD Mosfets for PWM backlight control and all other on-board parts **$70.00**

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kit including PCB and all SMD parts, LDR and blue LED **$12.50**

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hard-to-get parts: Q8-Q16, D2-D4, 150pF/250V capacitor and five SMD resistors **$35.00**

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PRINTED CIRCUIT BOARDS

NOTE: The listings below are for the PCB ONLY. If you want a kit, check our store or contact the kit suppliers advertising in this issue. For unusual projects where kits are not available, some have specialised components available – see the list opposite.

NOTE: Not all PCBs are shown here due to space limits but the SILICON CHIP Online Shop has boards going back to 2001 and beyond. For a complete list of available PCBs etc, go to *siliconchip.com.au/shop/8* Prices are PCBs only, NOT COMPLETE KITS!

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
INFRARED TO UHF CONVERTER	JULY 2013	15107131	$5.00
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PC BIRDIES	AUG 2013	08104131	$10.00
RF DETECTOR PROBE FOR DMMs	AUG 2013	04107131	$10.00
BATTERY LIFESAVER	SEPT 2013	11108131	$5.00
SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SiDRADIO (INTEGRATED SDR) Main PCB	OCT 2013	06109131	$35.00
SiDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
TINY TIM AMPLIFIER (identical Headphone Amp [Sept11])	OCT 2013	01309111	$20.00
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	08112131	$10.00
PORTAPAL-D MAIN BOARDS	DEC 2013	01111131-3	$35.00/set
(for CLASSiC-D Amp board and CLASSiC-D DC/DC Converter board refer above [Nov 2012/May 2013])			
LED Party Strobe (also suits Hot Wire Cutter [Dec 2010])	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
Li'l Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$12.50
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MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	99106141	$10.00
MICROMITE ASCII VIDEO TERMINAL	JUL 2014	24107141	$7.50
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OPTO-THEREMIN MAIN BOARD	SEP 2014	23108141	$15.00
OPTO-THEREMIN PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
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REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
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SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
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ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	1510815	$15.00
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LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$6.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116011/2	$15.00
PRECISION 50/60Hz TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
100DB STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	10107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116061	$15.00
MICROMITE PLUS EXPLORE 64	AUG 2016	07108161	$5.00
CYCLIC PUMP/MAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$10.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SC200 AMPLIFIER MODULE	JAN 2017	01108161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
60V 40A DC MOTOR SPEED CON. MOSFET BOARD	JAN 2017	11112162	$12.50
GPS SYNCHRONISED ANALOG CLOCK	FEB 2017	04202171	$10.00
ULTRA LOW VOLTAGE LED FLASHER	FEB 2017	16110161	$2.50
POOL LAP COUNTER	MAR 2017	19102171	$15.00
STATIONMASTER TRAIN CONTROLLER	MAR 2017	09103171/2	$15.00/set
EFUSE	APR 2017	04102171	$7.50
SPRING REVERB	APR 2017	01104171	$12.50
6GHz+ 1000:1 PRESCALER	MAY 2017	04112162	$7.50
MICROBRIDGE	MAY 2017	24104171	$2.50
MICROMITE LCD BACKPACK V2	MAY 2017	07104171	$7.50
10-OCTAVE STEREO GRAPHIC EQUALISER PCB	JUN 2017	01105171	$12.50
10-OCTAVE STEREO GRAPHIC EQUALISER FRONT PANEL	JUN 2017	01105172	$15.00
10-OCTAVE STEREO GRAPHIC EQUALISER CASE PIECES	JUN 2017	SC4281	$15.00
RAPIDBRAKE	JUL 2017	05105171	$10.00
DELUXE EFUSE	AUG 2017	18106171	$15.00
DELUXE EFUSE UB1 LID	AUG 2017	SC4316	$5.00
MAINS SUPPLY FOR BATTERY VALVES (INC. PANELS)	AUG 2017	18108171-4	$25.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER	SEPT 2017	01108171	$20.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER PANELS	SEPT 2017	01108172/3	$20.00/pair
3-WAY ADJUSTABLE ACTIVE CROSSOVER CASE PIECES	SEPT 2017	SC4403	$10.00
6GHz+ TOUCHSCREEN FREQUENCY COUNTER	OCT 2017	04110171	$10.00
KELVIN THE CRICKET	OCT 2017	08109171	$10.00
6GHz+ FREQUENCY COUNTER CASE PIECES (SET)	DEC 2017	SC4444	$15.00
SUPER-7 SUPERHET AM RADIO PCB	DEC 2017	06111171	$25.00
SUPER-7 SUPERHET AM RADIO CASE PIECES	DEC 2017	SC4464	$25.00
THEREMIN	JAN 2018	23112171	$12.50
PROPORTIONAL FAN SPEED CONTROLLER	JAN 2018	05111171	$2.50
WATER TANK LEVEL METER (INCLUDING HEADERS)	FEB 2018	21110171	$7.50
10-LED BARAGRAPH	FEB 2018	04101181	$7.50
10-LED BARAGRAPH SIGNAL PROCESSING	FEB 2018	04101182	$5.00
TRIAC-BASED MAINS MOTOR SPEED CONTROLLER	MAR 2018	10102181	$10.00
VINTAGE TV A/V MODULATOR	MAR 2018	02104181	$7.50
AM RADIO TRANSMITTER	MAR 2018	06101181	$7.50
HEATER CONTROLLER	APR 2018	10104181	$10.00
DELUXE FREQUENCY SWITCH	MAY 2018	05104181	$7.50
USB PORT PROTECTOR	MAY 2018	07105181	$2.50
2 x 12V BATTERY BALANCER	MAY 2018	14106181	$2.50
USB FLEXITIMER	JUNE 2018	19106181	$7.50
WIDE-RANGE LC METER	JUNE 2018	04106181	$5.00
WIDE-RANGE LC METER (INCLUDING HEADERS)	JUNE 2018	SC4618	$7.50
WIDE-RANGE LC METER CLEAR CASE PIECES	JUNE 2018	SC4609	$7.50
TEMPERATURE SWITCH MK2	JUNE 2018	05105181	$7.50
LiFePO4 UPS CONTROL SHIELD	JUNE 2018	11106181	$5.00
RASPBERRY PI TOUCHSCREEN ADAPTOR (TIDE CLOCK)	JULY 2018	24108181	$5.00
RECURRING EVENT REMINDER	JULY 2018	19107181	$5.00
BRAINWAVE MONITOR (EEG)	**AUG 2018**	**25107181**	**$10.00**
SUPER DIGITAL SOUND EFFECTS	**AUG 2018**	**01107181**	**$2.50**
DOOR ALARM	**AUG 2018**	**03107181**	**$5.00**

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CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

GPS or WiFi (NTP) clock using a PIC and an LCD screen

This simple project uses either a GPS module or a WiFi-equipped microcontroller module to give an accurate time and date display on a 16x2 alphanumeric LCD.

You can use just about any GPS module, as it extracts the time and date from the standard NMEA serial stream. Or you can use an ESP8266 microcontroller module with WiFi to emulate a GPS module while getting the time and date from internet time servers using NTP.

This latter method was described in detail in the April 2018 issue; see the article titled "The Clayton's 'GPS' time signal generator" (siliconchip.com.au/Article/11039).

The circuit is built around IC1, a PIC16F88 microcontroller. The serial output of the GPS module or WeMos module is fed to input pin 8 (RB2). If using a GPS module, it must use a TTL serial interface.

Software running on IC1, written in PICBASIC Pro, decodes the NMEA serial data and extracts the UTC time and date. It then applies the time zone offset for NSW/ACT/Vic/Tas and corrects for daylight saving.

The time and date are then sent to the 16x2 alphanumeric LCD module via a 4-bit data bus from digital outputs RA0-RA3 (pins 17, 18, 1 & 2). Output RA4 (pin 3) is used to drive the Register Select line (pin 4) of the LCD while output RB3 (pin 9) drives the enable line.

The LCD backlight is permanently powered via a 270Ω resistor from the +9V supply rail (to reduce dissipation in the 5V regulator) while contrast is adjusted using trimpot VR1. The unused pins of the LCD module are connected to ground.

Microcontroller IC1 has a 20MHz crystal oscillator and load capacitors connected between pins 15 and 16 in order to provide an accurate processor clock rate to get the correct serial port baud rate. Power is from a 9V battery and its output is regulated to 5V by a 7805 regulator.

The WeMos D1 Mini can draw a fairly substantial current, so the regulator is fitted with a small heatsink. This may not be necessary when using a GPS module.

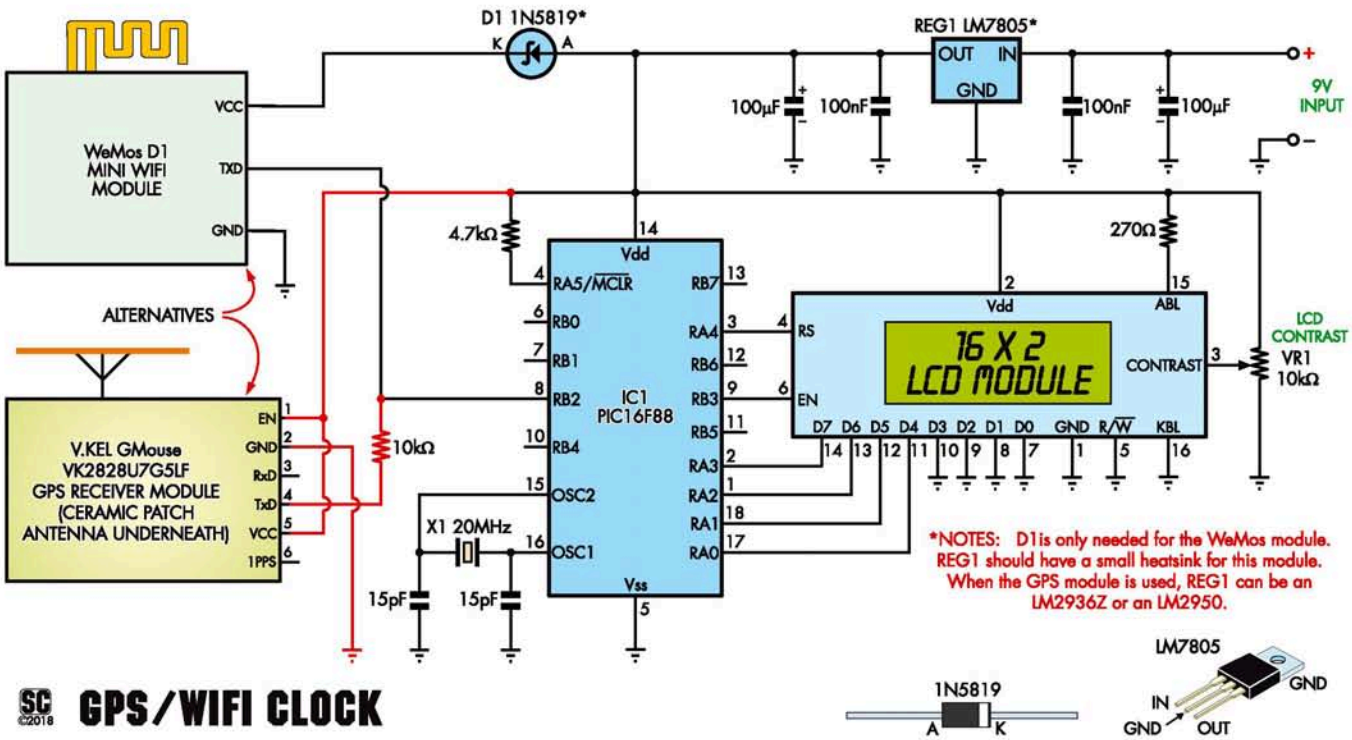
Also, 1A schottky diode D1 is provided to reduce dissipation in the WeMos module's onboard 3.3V regulator. While a GPS module will work with D1 in the circuit, it isn't required.

I have designed a small PCB for this project and the pattern can be downloaded from the SILICON CHIP website, along with the BASIC source code and HEX file.

The PIC16F88 can be programmed using the HEX file with most PIC programmers. The result is quite a compact unit.

Note that if you wanted to get the correct time outside one of the states mentioned earlier, you would need to modify the time zone settings in the BASIC source code and generate a new HEX file. You would need a copy of PICBASIC Pro to do this.

Les Kerr,
Ashby, NSW. ($60)



Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We will pay good money to feature it in Circuit Notebook. We can pay you by electronic funds transfer, cheque or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP Online Store, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au

36/48V 50A Charger Controller for golf carts etc

These small changes allow the 50A Battery Charge Controller to be used with a 36 or 48V lead-acid battery and charger, which are commonly used in golf carts. The Charge Controller was originally published in the November 2016 issue (siliconchip.com.au/Article/10413).

The November 2016 design was suitable for 12V and 24V batteries, selected by fitting a shorting block onto one side of header JP1. The changes described here make the 12V setting suitable for 36V batteries and the 24V setting suitable for 48V.

The changed components are highlighted in red on the circuit diagram. Seven resistor values change, including the three resistors associated with JP1 and four associated with test points TP1 and TP2. These changes affect the division ratios in these resistive dividers, to compensate for the battery having a higher voltage (eg, 48V compared to 24V).

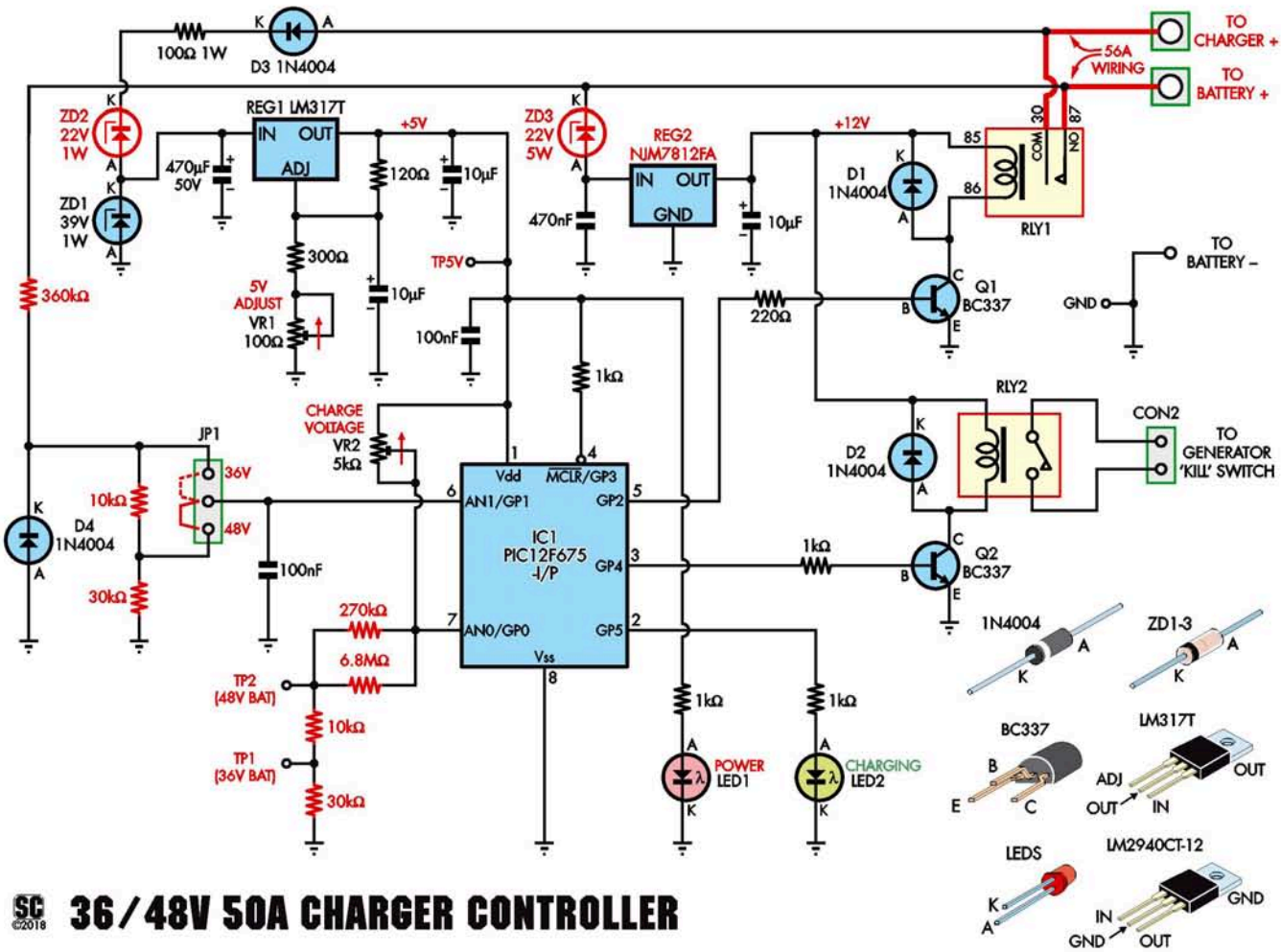
Other changes involve cutting two tracks and soldering zener diodes ZD2 and ZD3 in series with regulators REG1 and REG2 respectively. The zeners reduce the input voltages to the regulators to keep them within their maximum ratings and also share the increased dissipation.

You could avoid cutting the PCB track to REG1 by fitting an LM317HV (high voltage version) instead and omitting the zener but it would run hotter and you would also need to increase the voltage ratings of ZD1 (to around 59V) and its parallel 470µF capacitor (to at least 63V). Unfortunately, though, there are no suitable high-voltage alternatives for REG2.

With the changes shown here, the set-up and adjustment procedures are almost identical but note the new settings for JP1 and the re-assignment of TP1 and TP2. The only change in the set-up procedure is that the voltages at TP1 and TP2 now read as one-hundredth of the threshold setting, rather than one-tenth.

So for example, to set the fully charged voltage for a 48V battery to 57.6V, adjust VR2 to get a reading at TP2 of 0.576V.

SILICON CHIP



SC ©2018 **36/48V 50A CHARGER CONTROLLER**

Measuring air pollution with an Arduino-based module

Particulate pollution can cause serious lung problems, ranging from asthma (short-term exposure) to lung cancer (long-term exposure). So you need to keep your exposure to airborne particles below the recommended limits. But how do you know how what your exposure is? You can't sense very small airborne particles.

The circuit shown here can accurately measure the level of small airborne particles in its vicinity. The total cost of the parts is only about $50, not including the power supply.

It's particularly useful if you live in (or spend time in) a city with a constant low-level pollution problem, as is quite common in many Asian countries (including the sub-continent where the Author lives).

Particles with a diameter below 10 micrometres are known as PM_{10} while those with a diameter below 2.5 micrometres are called $PM_{2.5}$. PM_{10} pollution is bad because the particles can lodge deep in your lungs but $PM_{2.5}$ is even more insidious as it can actually pass into the bloodstream.

Sources of PM_{10} and $PM_{2.5}$ pollution include crushing and grinding operations, vehicle exhaust, vehicle brake and tyre particles, industrial pollution including smoke from coal power plants, wood burning, bushfires and fertiliser dust.

The recommended limit for exposure to PM_{10} (averaged over 24 hours) is 150µg/m^3 while the recommended limit for $PM_{2.5}$ is 35µg/m^3.

Circuit operation

Detection of PM_{10} and $PM_{2.5}$ pollution is accomplished using a Nova SDS011 Air Quality Sensor. It operates from a 5V supply and the sensor output is sent over a serial (RS-232 compatible) interface. Its measurement resolution is 0.3µg/m^3.

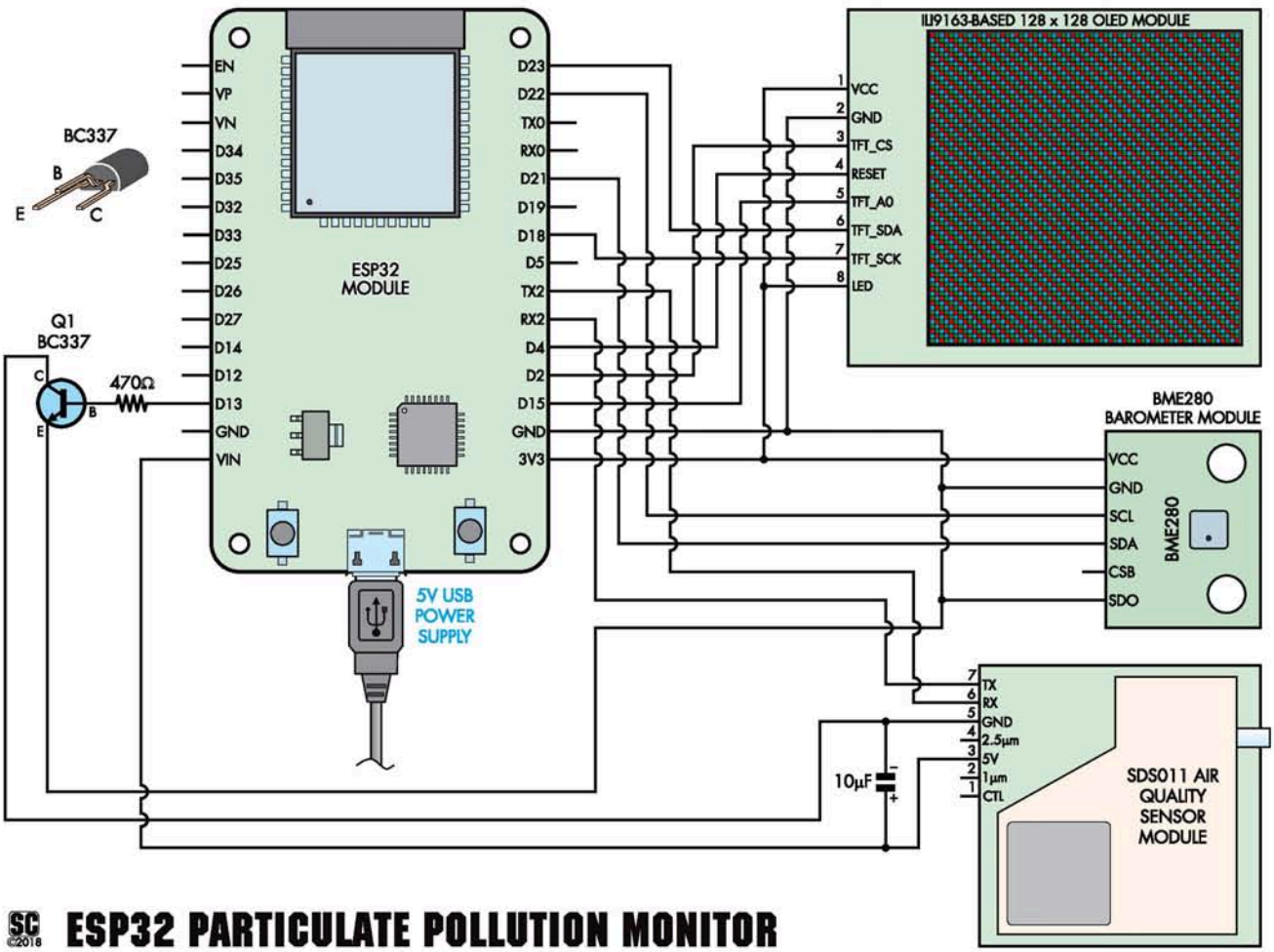
The particulate level measurements from the SDS011 sensor vary depending on relative humidity, therefore the design includes a BME280 barometer/thermometer/relative humidity sensor to compensate the measurements. This communicates with the Arduino using an I^{2}C serial bus.

Both sensors are monitored using an Arduino-compatible ESP32 module with WiFi. This is also connected to a 128x128 colour OLED display, which is used to display the measurement results.

That connection is made using an SPI serial bus, along with CS (chip select) and A0 (address) lines, which are driven by digital outputs on the ESP32 module.

NPN transistor Q1 is used to switch power to the SDS011 module so that it's only powered up when necessary. The only other components in the circuit are its 470Ω base current limiting resistor and a 10µF bypass capacitor for the SDS011 module.

USB power (5V) is fed directly to the ESP32 module and it powers that module, including its onboard microcontroller, as well as the SDS011 sensor, via its V_{IN} power pin. The output of its onboard 3.3V regulator powers the BME280 module and OLED screen.



ESP32 PARTICULATE POLLUTION MONITOR

To make the sensor portable, you could use a USB power bank. Or if you want it to run continuously in a remote location, you could use one of the Elecrow Solar Charger modules (SILICON CHIP Cat SC4307/4308) along with a lithium-ion or lithium-polymer cell and a small solar panel. These boards have a USB socket which can power the ESP32 board using a standard USB cable.

Software

There is an Arduino library available for interfacing with the SDS011 but it relies on the SoftwareSerial library, which doesn't work properly with the ESP32.

The ESP32 has three hardware serial ports so I decided to modify the library to use one of these instead, using the HardwareSerial object rather than SoftwareSerial.

The modified library is supplied in the download package (in the file "processdata.h"), along with the Arduino sketch code. Communication is via the second serial port which uses the TX2 and RX2 lines.

The SDS011 module has a specified sleep current of 2mA but when I sent sleep commands to my module, the supply current didn't drop consistently. That is why NPN transistor Q1 is used to disconnect the module's ground connection when it is not being used. This is controlled using digital output D13, with a high level on that pin enabling power to the sensor.

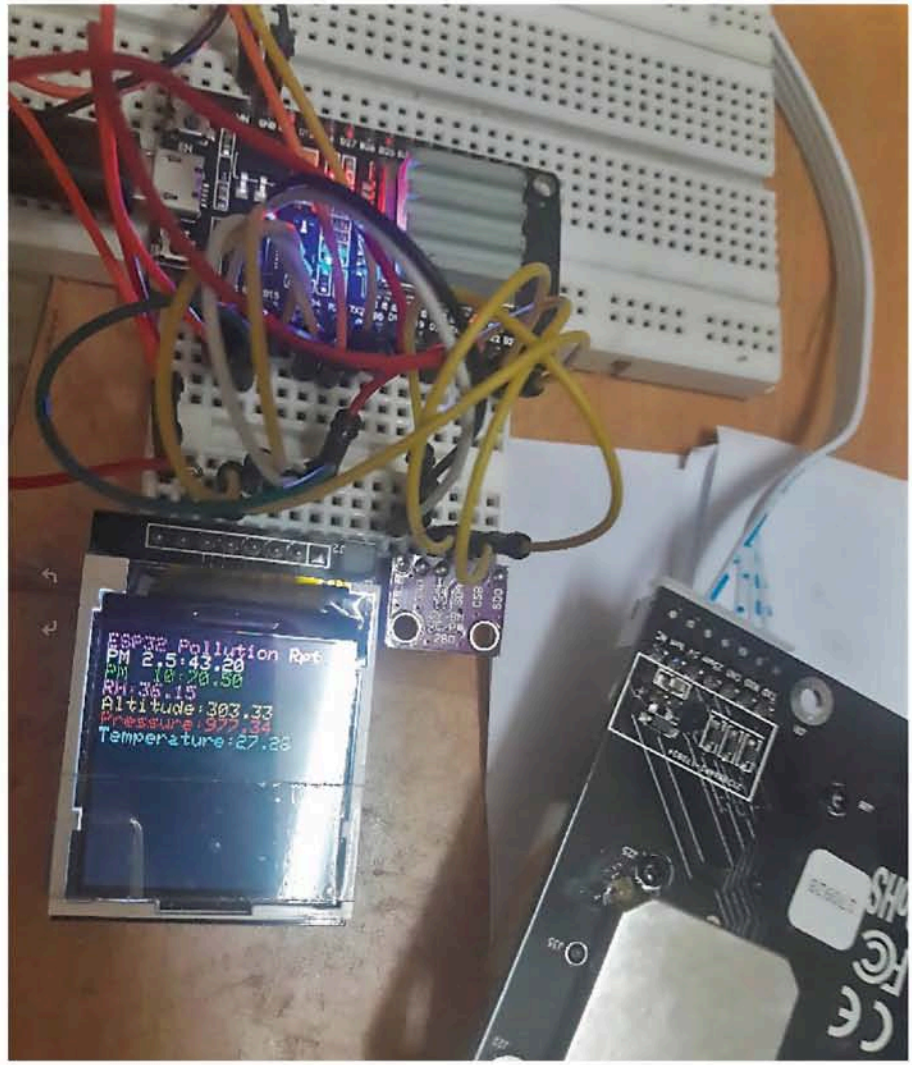
As well as the pollution levels being displayed on the OLED screen, they are also uploaded to the cloud data service website, ThingSpeak. See the article "Logging data to the 'net using Arduino", starting on page 92 of the September 2017 issue for details (siliconchip.com.au/Article/10804).

This means that you can position this unit remotely, as long as it has power and access to a WiFi network, then view a plot of the pollution levels over time from anywhere via the internet.

Software set-up

We previously explained how to set up a ThingSpeak account in the February 2018 article titled "Water Tank Level Meter with WiFi". For details on how to set up an account, see siliconchip.com.au/Article/10963

Once you have set up an account on the thingspeak.com website and created a "channel", you will have a channel ID and write API key. You can then set up and name the eight data streams within that channel. Use the following names (or something similar) for channels 1-5: "PM2.5 (µg/m^3)", "PM10 (µg/m^3)", "Temperature (C)", "Atmospheric Pressure (hPa)" and "Relative Humidity (%)".



The finished particulate monitor will display the $PM_{2.5}$ & PM_{10} reading (µg/m^3), the relative humidity (%), altitude (m), pressure (mbar) and temperature (°C).

You also need to have a recent version of the Arduino IDE installed on your system (Windows, macOS or Linux), along with the ESP32 Board files. The procedure to install these required board files is given at the following link: siliconchip.com.au/link/aaiw

Now edit the Arduino sketch ("ESP32_SDS011_BME280_thingspeak.ino"). About twenty lines down from the top of the file, there are a number of parameters that you need to change.

These include your WiFi network SSID ("ssid") and password ("pass"), your ThingSpeak channel number ("myChannelNumber"), and its write API key ("myWriteAPIKey").

Having wired up the modules as shown in the circuit diagram and plugged the ESP32 board into your PC, ensure the correct port number is selected in the Tools → Port menu and that the correct board type is selected under the Tools → Board menu (eg, "ESP32 Dev Module" or "DOIT ESP32 DEVKIT V1"). Then select the Sketch → Upload option.

The programming process takes around 15-30 seconds and once it is finished, the unit should spring into life. As well as viewing the data on the OLED screen and via thingspeak.com, you can also see the sensor output by selecting the Tools → Serial Monitor menu option.

Bera Somnath,
Vindhyanagar, India. ($90)

Dual high-power sinewave generator

This dual Wien-bridge circuit using the L272M power op amp is designed mainly for testing and characterising public address systems, intercoms and the like.

It can produce sinewaves over a range of frequencies, with enough power to drive long lines, 600Ω transformers, 100V transformers and the like.

The L272M is mainly used in control applications such as for servos, motors in CD/DVD/Blu-ray players and so on.

However, it can also be used for other purposes. It has an output current of up to 1A, a gain-bandwidth product of 350kHz, can run off supply rails between ±2V and ±14V and has a specified audio distortion level of 0.5%, which is good enough for voice systems.

OUT1 can be configured to produce a 300Hz or 1kHz signal while OUT2 can be configured to produce a 2kHz or 3.3kHz signal.

This is selected by switch S1 for OUT1 and S2 for OUT2. They change the component values in the Wien-bridge oscillator circuits built around IC1a and IC1b. Potentiometer VR1 varies the level of OUT1 while VR2 varies the level of OUT2.

The challenge with an oscillator is that you want substantial positive feedback for fast and reliable start-up, but the feedback needs to drop back to unity gain once oscillation has been established in order to prevent the circuit overloading and the output signal becoming very distorted and possibly shifting away from the desired frequency.

One of the tricks used with a Wien bridge in the oscillator configuration is to replace one of the resistive parts of the bridge with an incandescent lamp.

This acts as a resistor but as the lamp warms up, its resistance decreases and that will then have the effect of reducing the gain as the oscillator output amplitude increases.

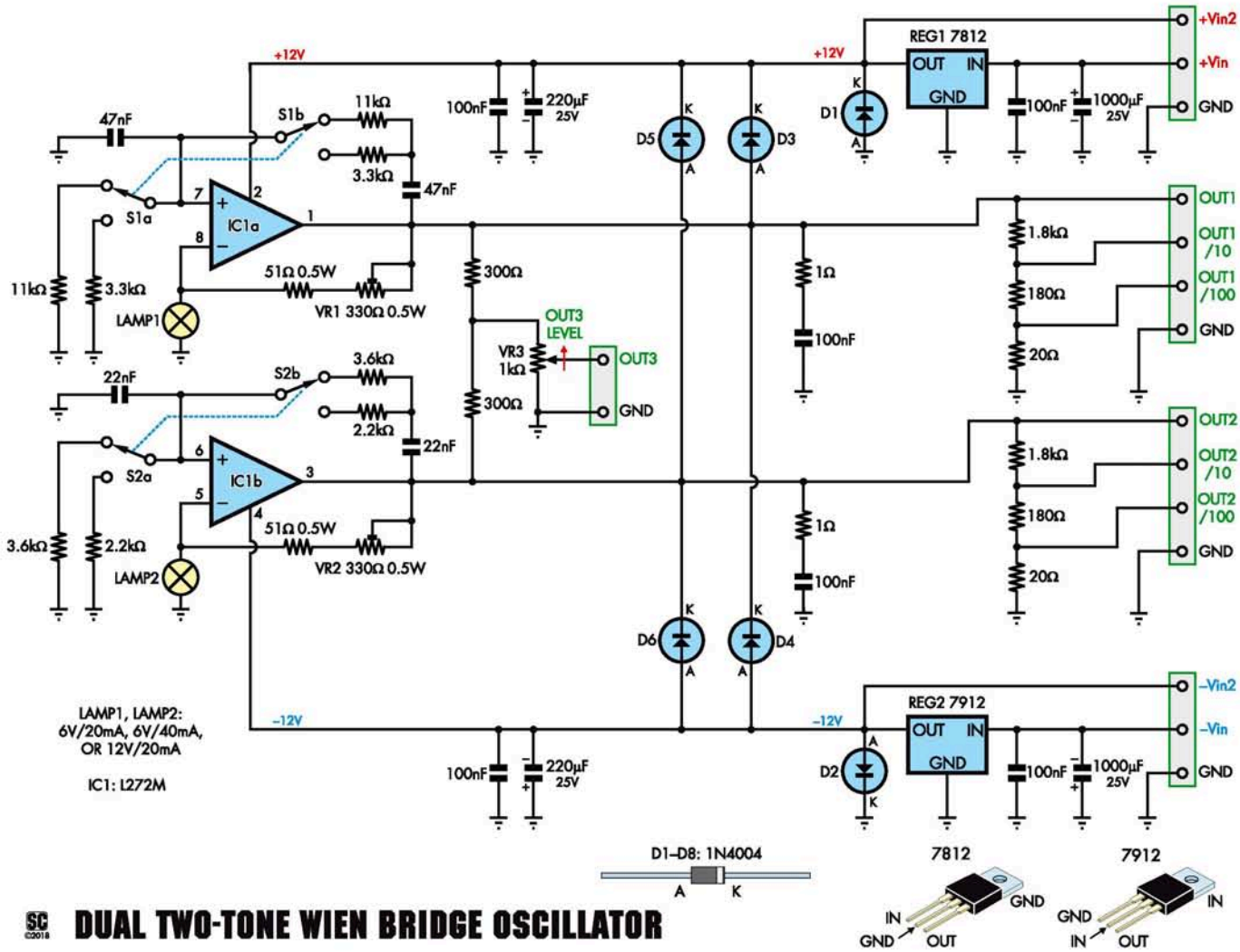
This gain stabilisation is what allows the circuit to produce a clean sinewave.

The resistors and capacitor pairs in the Wien bridge circuit are of equal value across the two sides of the bridge, however, this is not a strict requirement, it simply makes the calculations easier.

While the circuit uses fixed values, you could connect potentiometers in series with the resistors to adjust the frequencies.

A dual-gang potentiometer, to vary the halves of the bridge together, would probably give a wider range of adjustment.

Each oscillator output has a Zobel network for stability (required for many "power op amps"), comprising



DUAL TWO-TONE WIEN BRIDGE OSCILLATOR

a 1Ω resistor in series with a 100nF capacitor.

Each oscillator has a direct output, as well as outputs with 1/10th and 1/100th of the full amplitude.

Note that these attenuated outputs have a much higher impedance and so will not supply anywhere near as much current or power as the unattenuated outputs.

A mixed output is also available, at OUT3, combining the signals of the two oscillators using two 300Ω resistors. Its level is adjustable using potentiometer VR3.

The circuit is powered from unregulated split rails (eg, the rectified output of a transformer) at $+V_{IN}$ and $-V_{IN}$, regulated to ±12V by linear regulators REG1 and REG2. Or you can feed in already regulated split rails at $+V_{IN2}$ and $-V_{IN2}$.

As indicated on the circuit diagram, you can use various small incandescent lamp globes for LAMP1 and LAMP2, including 6V/20mA (120mW), 6V/40mA (240mW) and 12V/20mA (240mW) types.

Petre Petrov,
Sofia, Bulgaria. ($50)

DIY magnetic connectors

Years ago, Jaycar used to have very useful magnetic electrical connectors. They were great for testing AA and AAA cells and 9V batteries. Unfortunately, they are no longer available.

Recently, I was browsing eBay and I found some 5 x 5 x 5mm neodymium rare earth magnets and wondered whether I could solder wires to them.

They only cost $2 for 10 magnets so I decided to take a punt. When they arrived, I found them quite easy to tin and solder to. So I set about making my own magnetic connectors.

I stripped some solid core hookup wire (also known as "Bell" wire, in this case, stripped from some old four-wire phone cable) and tinned the ends. I also tinned a small spot on each magnet (see photograph below).

I found the best way to do this was with a very hot iron used quickly. This avoids overheating and demagnetising the magnet. Attaching the magnet to a large piece of ferrous material will help to draw heat away from it and hold it in place while it is soldered.

Interestingly, my old Scope iron worked best as its copper tip doesn't get grabbed by the magnet, unlike the iron tip on my Hakko.

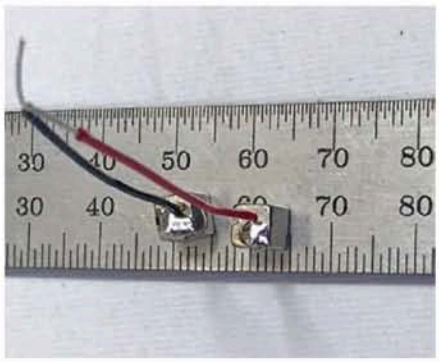
I carefully bent the short end of the copper wire then quickly soldered it to a magnet. As you can see from the photograph to the right, these magnetic connectors mate perfectly to AA cells and there is no tendency for them to fall off; it takes some force to pull them off the cell.

If you have a 3D printer, you can make my "Universal Magnetic Connector". The design is available from www.thingiverse.com/thing:2825640

You can find the eBay listing for the magnets at www.ebay.com.au/itm/253151008050 ("10pcs N42 Cube Super Strong Magnetic Neodymium Rare Earth Magnets Block 5x5x5mm").

Geoff Cohen,
Nelson Bay, NSW. ($60)

Shown right are the tinned magnets attached to a battery to help measure its voltage.



The neodymium magnets are tinned with a small amount of solder and then attached to hookup wire.

Two pairs of magnets used to create a locking door on a 3D printer with power fed through (shown slightly larger than life size).

VINTAGE RADIO

By Associate Professor Graham Parslow

AWA 1963 model B13 stereogram

If you watch the popular "Endeavour" detective series on ABC TV, you will know that the young D.S. Morse is a classical music enthusiast who listens to LP records on a portable record player similar to the AWA model featured here. The series is set in the 1960s when valves still ruled and stereo sound was the latest "big thing".

The 1960s were the best of times in many ways. If we take Charles Dickens' introduction to A Tale of Two Cities then we can also reflect on the 1960s as the worst of times. Russia and the USA were engaged in a cold war that looked like it could annihilate the planet in nuclear war. Many people built bomb shelters.

On the other hand, the youth of that time were the most liberated generation that the planet had seen. The post war baby boom had produced prosperity and teenagers who revelled in rock and roll, songs of protest, listening to the top 40 and buying 45 RPM records. And LP record albums were coming out in stereo.

With rising interest in stereo sound, it is not surprising that all major radio manufacturers in Australian were making stereograms both in portable and furniture format that were more affordable than the radiograms that parents previously aspired to have in their lounge room.

Portability was a new feature that departed from the tablegrams manufactured in the 40s and 50s. Teenagers could take their music with them to party with friends.

AWA, who manufactured the portable stereogram featured in this article, was the largest electronics manufacturer in Australia in 1963. Following behind them was Astor, Kriesler and HMV, all of whom offered similar portables.

Examples from Astor, Kriesler and HMV in the author's collection are shown in this article. They all have timber cabinets covered in fabric or leatherette, with a carry handle for transport like a suitcase.

In 1963 it still made sense to purchase a valve unit, relative to the new transistor technology. The valve units arguably sounded better and produced higher volume.

Idler wheel

The AWA unit featured here performs well as a radio but it has a problem that is common to all record players of this vintage which have idler-driven turntables. The idler wheel is placed between the stepped spindle of the turntable motor and the inside rim of the turntable. After 50 years or more, the idler wheel will be either perished or seriously cracked.

In some cases after many years of disuse, the idler wheel may be so bad-

The AWA B13 has a hand-span tuning dial with stations for all Australian states. Note the combined tone control and power switch.

ly perished that it is a glutinous mass stuck to inside rim of the turntable. Or maybe the idler wheel has been left engaged for many years and now has a serious flat spot. If you do manage to get it to run, it will have intolerable wow.

In all these cases you need to obtain a replacement idler wheel before you can restore the record player function. That is just the first hurdle. You will find there are a number of online companies that can either replace or make new idler wheels but they are based in the USA and the cost will be high.

If you are handy with a lathe and can source rubber discs of the right consistency, such as cistern rubber parts from hardware supplier Bunnings, you make may able to make a new idler wheel.

Of course, you will also need to source a new replacement cartridge. Record players of this era used turnover crystal or ceramic (piezoelectric) cartridges with two styli, one for playing 78 RPM records and one for playing 45 RPM and 33 RPM vinyl records.

It is most unlikely that any 60-year old crystal cartridge will still work and even if it did, the styli are likely to be seriously worn or broken off. Fortunately, a range of these cartridges are available for most record changers used at the time, such as BSR and Collaro.

At the time of writing this story, I had not been able to do anything about the record changer and its idler wheel and cartridge. Instead, I concentrated my efforts on restoring the cabinet and chassis.

Valve radio technology was mature in the early 1960s and this AWA set follows a well established format and valve complement. Somewhat surprising is the omission of a ferrite aerial.

Instead, the front end has a conventional aerial coil needing an external loop antenna. Because of the area available below the turntable, a loop antenna has been stapled to the plywood base.

Circuit design

This is really an AM tuner with an integrated stereo amplifier. The circuit is quite simple with a line-up of just six valves: a 6BE6 pentagrid converter (mixer oscillator), a 6N8 double-diode pentode, a 12AX7 twin triode, two 6AQ5 pentodes and a 6X4 full wave rectifier.

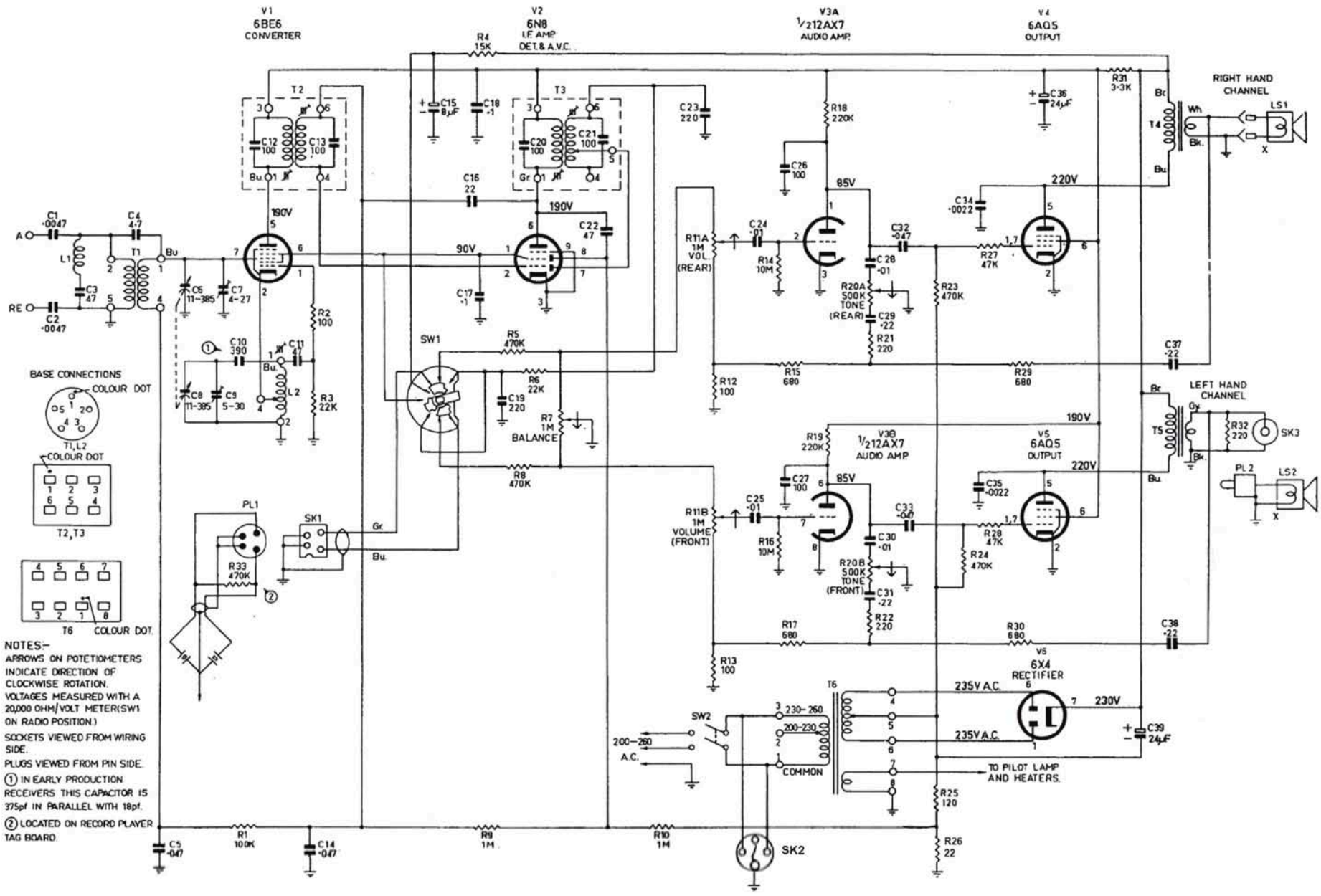
The signal from the loop antenna is fed into the aerial coil (T1) which supplies the grid of the 6BE6 and coil L2 is configured as a Hartley oscillator, with the oscillator signal fed into pin 2 of the same valve. Both the aerial and oscillator coils are tuned by the 2-section tuning gang.

The 455kHz difference signal from the 6BE6 converter appears at the plate and is tuned by the first IF transformer T2. Its secondary is fed to the grid (pin 2) of the 6N8 whereupon it is amplified and appears at the plate (pin 6) of the 6N8 to be tuned by the second IF transformer T3.

The two diodes in the 6N8 generate the AGC signal and perform demodulation. The 455kHz signal from the plate (pin 6) is fed via capacitor C22 to the diode at pin 8 and the resulting negative voltage is fed to the control

Two of these three portable radiograms of the period were stereo, both with a second channel speaker in the lid which had to be detached for listening to records. The three models shown above are a 1964 Astor G10L, 1955 Kriesler model 11-76 and 1966 HMV Bahama O3-8K.

AWA. 6 Valve Stereophonic Port. R/G. MODEL B13.



The tuner circuit is quite conventional, with the two diodes in the 6N8 valve used for demodulation and generating the AGC control voltage. Note the Baxandall tone control which provides treble boost and cut. Bass boost was not available in most portables because of the risk of acoustic feedback to the turntable.

Australia's electronics magazine siliconchip.com.au

grid of the 6BE6 via resistors R9 and R1 while the 6N8 gets its AGC via R9 and the secondary of transformer T2. Strong signals generate a negative AGC voltage and lower the gain of the 6BE6 and 6N8.

At the same time, the modulated 455kHz signal from the secondary winding of T3 is fed to pin 7 of the 6N8 and the resulting demodulated signal appears at the secondary of T3 across filter capacitor C23. Further filtering is provided by T6 and C19.

The radio/phono pickup selector switch SW1 feeds the demodulated (mono) signal from the tuner (or the stereo signals from the ceramic cartridge) to the 2-channel audio amplifier. In the latter mode, the 90V supply the screens to the 6BE6 and 6N8 is disconnected to prevent radio station break-through when listening to records.

The separate signals from the selector switch to the amplifier channels are fed via 470kΩ resistors (R5 & R8) to the balance control potentiometer R7 and then to the separate volume controls.

Stereo amplifier

The 2-channel audio amplifier consists of a 12AX7 high gain twin triode feeding into two 6AQ5 pentode output valves. This well-tried combination was ultimately replaced in later radios by the 6GW8 triode pentode valve.

When playing records, the speaker in the lid became the right-hand channel while the speaker in the front of the cabinet became the left-hand channel.

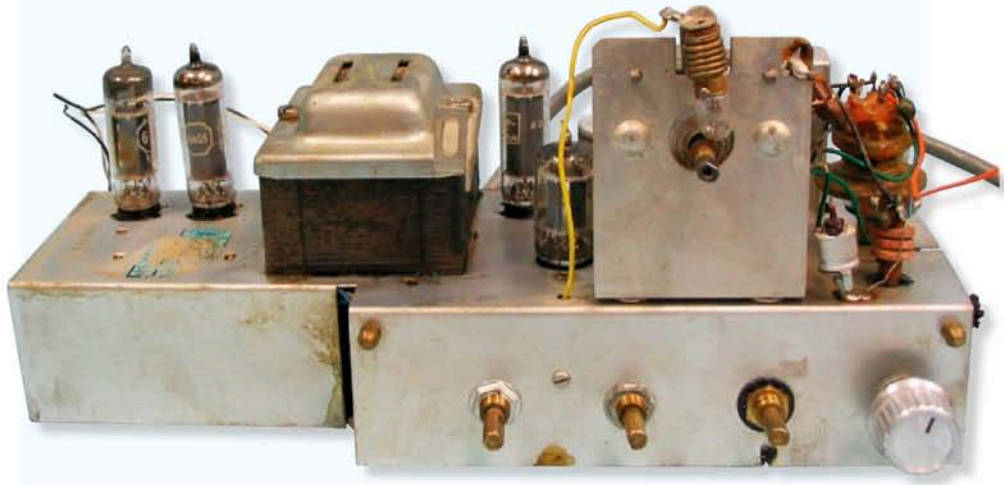
In each channel, negative feedback from the secondary winding of the output transformer was applied via C37 (C38), R29 (R30) and R15 (R17) to the bottom leg of the 1MΩ volume control (RM11A/B). The feedback signal is also applied to the tone control network involving 500kΩ dual-gang potentiometer R20A (R20B), via R21 (R22).

The resulting tone control gives variable treble boost or cut and this must be one of the first instances of a Baxandall tone control stage in valve consumer equipment. Prior to this, tone controls in valve amplifiers tended to be passive networks.

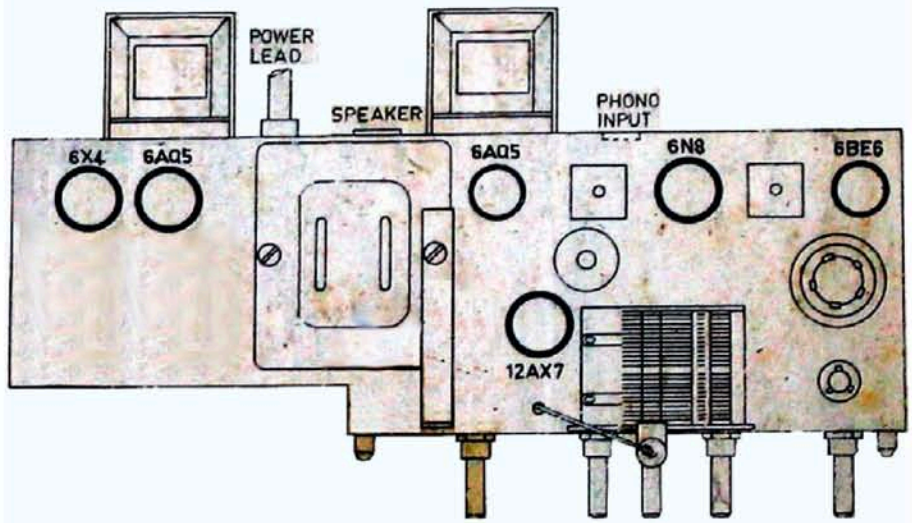
Note that the DPST mains switch is integral to the stereo tone control potentiometer, not the volume control.

Interestingly, the primary wind-

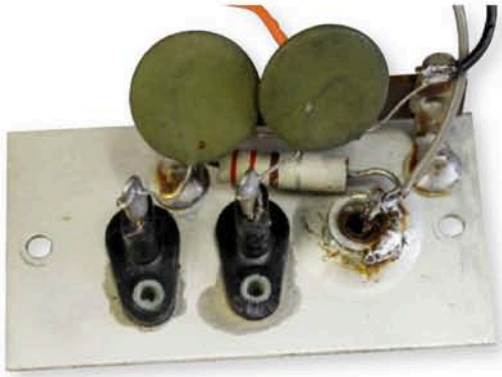
The chassis is crammed into the front of the case and the two audio out transformers hang off the rear. The orange wire is the aerial loop.



This view shows the front of the chassis which has a cutout section on the left to accommodate the front-mounted speaker.



The chassis layout is on a paper label on the base of the cabinet. Note the pilot lamp which provides illumination behind the circular dial.



This metal plate carries the isolating capacitors for the external aerial and the RCA socket for the lid-mounted loudspeaker.

ing of the power transformer has a tap to cater for mains voltages of 200-230VAC or 230-260VAC. That voltage range is appropriate today since domestic solar panels commonly now boost the mains voltage in some areas to well over 250VAC.

The chassis of the unit has been crammed into the front of the case as can be seen on the previous page. The orange wire used for the loop antenna can be seen connected to the aerial coil in the photograph showing the front of the chassis (right hand side in the photograph).

The end of the loop antenna terminates at the back of the cabinet in a trio of connections for aerial, earth and the left-hand speaker.

The photograph above of the back panel plate shows C1 and C2, both low voltage ceramic 4.7nF disc capacitors, which couple signals to the external aerial and earth. Adjacent to the aerial and earth is the RCA socket for the left-hand speaker, which is mounted in the removable lid.

The RCA socket was loose and making poor earth contact so it was anchored with solder. The internal socket sheath that makes contact with the central RCA pin had expanded and was making unreliable contact.

Fortunately, it was possible to use a small precision screwdriver to close up the socket sheath and restore reliable connection. The rear panel also has R32 (220Ω) that acts as a dummy load if the extension speaker is not plugged in.

Restoration

At the time this unit was purchased through eBay, the author was time-poor. One aspect of the transaction that did not take much time was the collection of the unit.

Against the odds the seller worked in the building opposite the author's. Sometimes the stories that go with acquiring a vintage radio make the radio far more interesting.

There was no great story to be told when I collected this one. At home the unit performed feebly but at least showed that it could work. The high tension was measured at 62V so even achieving feeble operation was remarkable. It stayed on a shelf for ten years, always niggling at me ever so slightly.

Then the Historical Radio Society of Australia (HRSA) published a series of eight circuit books, including the AWA model B13 in book number four. The books are of valve radio circuits, all edited by Philip Leahy (see www.hrsa.asn.au/books/index.htm). They are only for purchase by HRSA members, but annual membership is a modest $40 and includes four editions of the HRSA journal Radio Waves.

Collectively the HRSA circuits extend well beyond the scope and time covered by the Australian Official Radio Service Manuals, covering from 1935 to 1955.

With a circuit in hand, and no longer so time-challenged, the time came to restore this unit. Removing the chassis is straightforward but tedious due to the large number of screws involved. The skinny chassis with a slightly flared front section and output transformers on the rear is unstable in any position except upright.

Working conveniently underneath the chassis necessitated some sort of stable support, so fabricating a jig was the first task. A tripod arrangement, as shown above, worked well.

The high tension was 62V, just as measured a decade before and the power consumption was low at 23W. The first thought was that a paper capacitor decoupling high tension to valve plates or screens had become leaky and was dragging the voltage down.

None of the relevant capacitors were getting warm but that can be misleading when only 62V (or less) is involved. The decoupling capacitors were replaced with the result being absolutely no difference.

The first HT filter electrolytic was getting slightly warm, but hindsight suggested that this was because of proximity to resistors that were warm. Replacement of the suspicious electrolytic did nothing.

Looking intently below the chassis can obscure problems that reside above the chassis. Taking a peek above chassis showed that the 6X4 rectifier had been "cooked" with a brown stain on the inside of the envelope; a characteristic of valves that have been overloaded and dissipated intense heat.

A replacement 6X4 brought about a dramatic improvement. The high tension rose to 180V DC (it should be 220-230V) and power consumption rose from 23W to 62W.

The audio output level was still a bit low and the sound was distorted. Measuring the grid bias to the 6AQ5 output valves was the final clue to the core problem that had disabled this set.

The bias was a negligible -0.3V, driving the 6AQ5 valves into high conduction, explaining why the original 6X4 had been destroyed.

Bias resistor R25 had fallen from 120Ω to 70Ω and was replaced. This could not account for all of the degradation of the bias voltage so it was a matter of replacing the usual suspects – the coupling capacitors between the 12AX7 and the 6AQ5s.

In most sets I would have done this routinely but this one has a metal plate installed over the socket of the 12AX7 as a shield against noise signals entering the preamplifier.

Removing the plate allowed access to the tag strip holding the two coupling capacitors. One of the two capacitors was buried and could not be conveniently removed, so a pig-tail was snipped to take it out of circuit.

With both C32 & C33 replaced, the set came to life. Power consumption decreased from 62W to 47W and the 6AQ5 bias measured a reassuring -8.7V, perfect for producing undistorted sound. HT values were spot on to the values given in the AWA circuit. After that, it worked well.

The sound quality is surprisingly rich and satisfying but it is also a bit strange at first because sound from the two channels comes from the front and top of the unit when the lid is down.

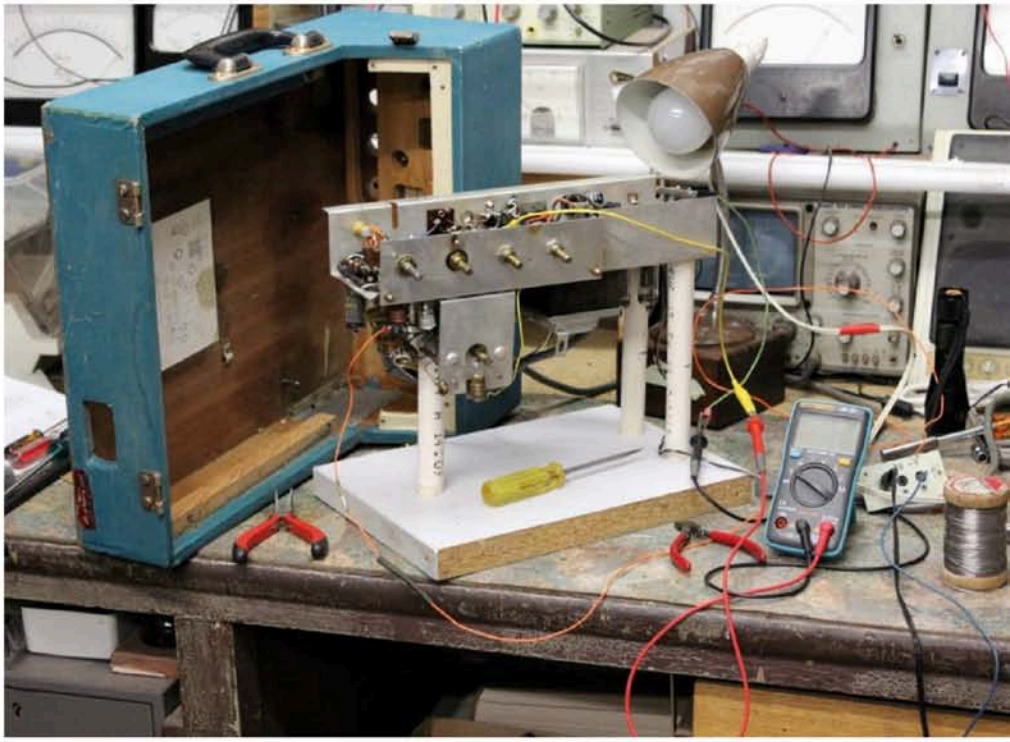
But in practice, that's not how you would listen to this unit because the rear speaker needs to be tilted up to

access and use the turntable. If you played a record with the lid lowered, this would result in howl due to the proximity of the speaker to the turntable.

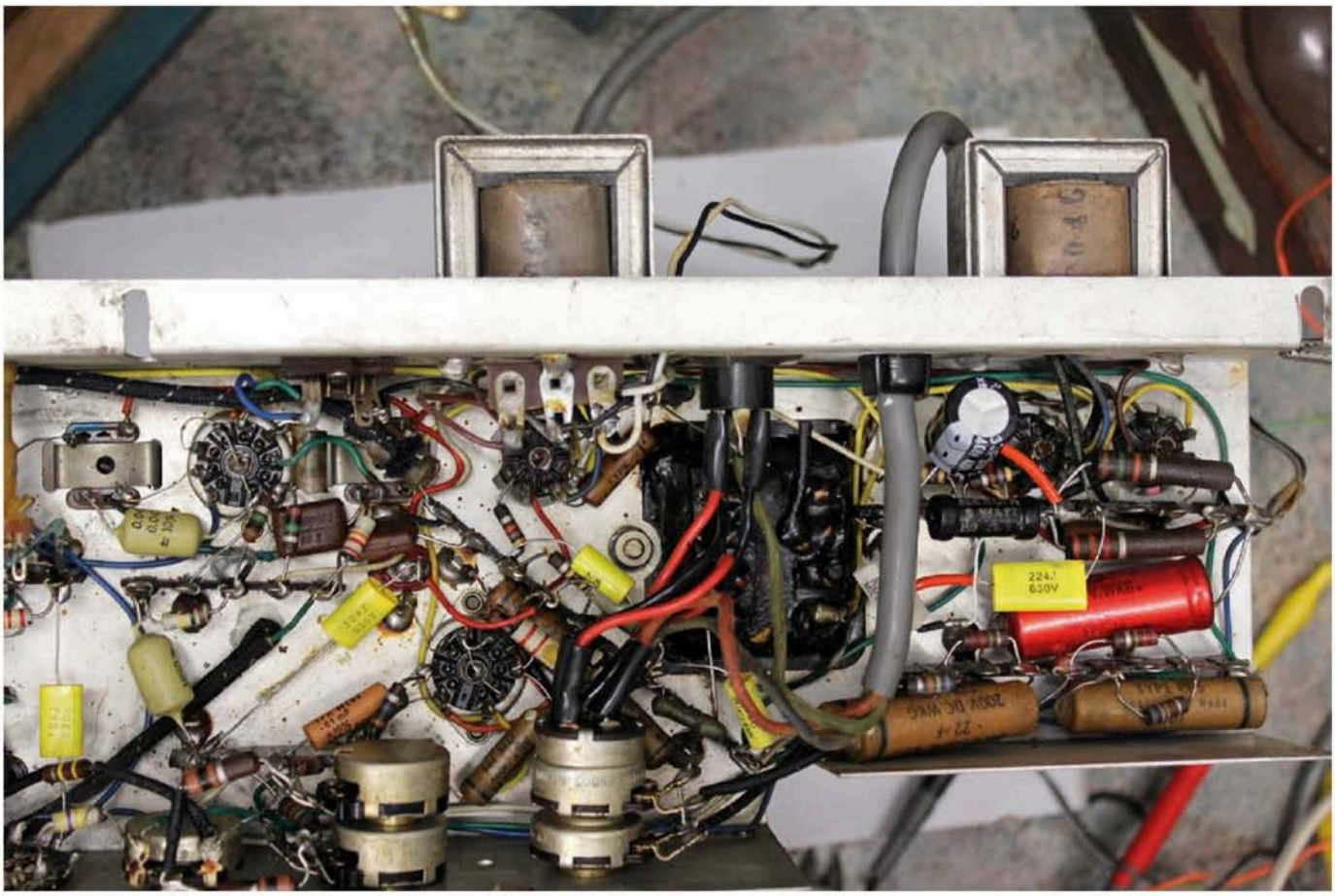
These portable record players proved to be a transitory technology. In 1963, the year this record player was made, Philips introduced the compact cassette tape for dictation machines with no idea that this would become the portable music technology of the immediate future (see the June 2018 article by Ian Batty; siliconchip.com.au/Article/11136).

On the other hand, the large console-style radiogram was superseded by the stereogram, having two loudspeakers in the one cabinet, but these were ultimately superseded by home entertainment centres combining AM/FM stereo tuners plus CD, tape cassette and record players.

And now, all of those have been largely consigned to the rubbish heap of technology by tablets and smartphones. SC



Working on the upturned chassis is tricky without a tripod arrangement to prevent the valves being damaged.



This photo of the chassis after restorations shows that most of the components are reasonably accessible from undearneath the chassis. The repair consisted of replacing the two coupling capacitors (C32/33) and the bias resistor (R25), with the 6X4 rectifier valve replaced on the top of the chassis. Note the DPST mains switch on the rear of the dual ganged tone control potentiometer.

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

How to listen to a Smart TV with hearing aids

I am looking for information on how to connect a transmitter to my Smart TV so that I can listen to it using my hearing aids.

I have a selector switch on my left hearing aid that I can switch to listen to T-coil public address type systems. As is typical of many modern TVs, mine does not have RCA analog outputs. (L. N., King Creek, NSW)

● You haven't given us a brand or model number for your Smart TV but they almost universally have headphone sockets.

It is not necessary to connect headphones via a cable. You can connect a Bluetooth transmitter (available for a few dollars from eBay) to your TV's headphone output socket and then listen with battery-powered Bluetooth headphones. The headphones need to be paired with the transmitter before you can use them.

Mind you, using the headphone socket on your TV normally disables the TVs internal speakers and that is a problem if someone else is watching TV with you. In that case, you may need to purchase a small DAC, which you can connect to the TV's digital audio output (TOSLINK or S/PDIF). Jaycar has two suitable units, Cat AC-1715 or AC-1633 (see page 451 of the 2018 Jaycar catalog).

You can then use a cable with stereo RCA plugs on one end and a stereo 3.5mm plug on the other to connect the DAC output to a Bluetooth audio transmitter.

If you want to use the T-coil (Telecoil) facility on your earphones, you would need to install a hearing loop in your listening room (either around the skirting boards or underneath the floor). This loop will need to be driven by an audio amplifier and to obtain the audio signal to drive it from your smart TV, you will need a DAC module as described above.

To find out more about installing hearing loops, you should refer to the articles on this topic in the September & October 2010 issues of SILICON CHIP; see siliconchip.com.au/Series/11

AM transmitter oscillator not running

I have just completed the AM Radio Transmitter from the March 2018 issue (siliconchip.com.au/Article/11004) and used your recommended metal film resistors and NP0 ceramic capacitors. I followed the assembly very carefully and the checkout and adjustment procedure slowly and painfully but it does not work.

All the voltages seem to be within reason. I found that the 2.2MΩ resistor was connected to the collector of Q2, and not to the base on the printed board. This now rectified. Is this a double-sided board?

I see no waveform from the Q1 oscillator at the junction of T1 and the 4.7nF capacitor. There's no modulation on pin 1 of IC1 and obviously none on pin 12. I have checked all solder joints and they appear to be OK

Any help would be appreciated. I have found this to be one of the most frustrating projects to fault-find. A friend recently built this project and also had much difficulty in getting it to operate but finally, he has. (R. W., Brisbane, Qld)

● The PCB is a single-sided design, ie, there are tracks on one side only. But it is manufactured as a double-sided board since the cost is the same and this gives more secure solder joints due to the plated through-holes.

You are right that there is an error in the board design where the 2.2MΩ resistor was wired up incorrectly and your fix sounds correct. No other changes should be necessary.

If you are checking for an oscillator waveform with an oscilloscope, the first place to check is at pin 10 of IC1. This is the output of the carrier oscillator.

There will be no modulation at pin 1 unless you have connected an audio source to the stereo input socket and VR2 is adjusted accordingly. Of course, you should have initially checked that the supply voltage is correct at 12V and it present on the collectors of Q1 & Q2.

The Q1 oscillator is a semi-independent part of the circuit and is critical for transmitter operation. If this oscillator is not running then the transmitter cannot possibly work.

That it is not running suggests a problem with either Q1 or T1 or perhaps a bad connection to one of the passive components. Please check for 12V at the collector of Q1. The base should also be close to 12V if it is not oscillating.

If it still won't oscillate, try replacing Q1. You could remove the 4.7nF capacitor coupling the output of T1 to IC1 to separate the oscillator so you can test it in isolation, but really, that should not be necessary.

Bug in OLED NTP Clock code

I am writing regarding the Circuit Notebook item on the OLED NTP Clock on page 82 of the February 2018 issue (siliconchip.com.au/Article/10975). This is based on an ESP32 module which is programmed using the Arduino IDE.

I built the circuit and uploaded the sketch (which I got from your website) but I could not get it to connect to the internet until I took out the comment symbols (//) at the start of this line:

```
// WiFi.begin(ssid, password);
```

Once that was done, it worked immediately. If you make this change in the sketch that is available on your website, it should help others who are building this circuit.

Why was this line commented out? I would like to thank the author of the article, Bera Somnath. This is my first time using an ESP module. I think it has lots of possibilities. (P. S., Narrogin, WA)

● While it is true that removing the comments from that line will make the software work, the bug is actually

elsewhere and that change simply covers it up. The real problem is with the line that reads:

```
counter = preferences.getUInt
  ("counter", 0);
```

It should actually read:

```
counter = preferences.getUInt
  ("counter", 1);
```

This sets the correct default value of the "counter" variable so that it knows which wireless network it should be connecting to the first time the sketch is loaded.

But if you're only using a single wireless network (rather than the primary and alternative intended in the original software) then your solution should work just as well.

Source of Super-7 AM Radio parts

I recently started collecting parts for the Super-7 AM Radio project (November-December 2017; siliconchip.com.au/Series/321) and while I enjoy the detective work involved in sourcing parts that are not identified by the company and part number in the parts list, I have been unable to identify the 100mm speaker.

The pictures on pages 69 and 72 of the December 2017 issue show a speaker with a round mounting flange. The equivalent speakers from Jaycar and Altronics all seem to have a rectangular flange so would not be suitable. What speaker have you used in this project?

Also, in the picture on page 66 of the December 2017 issue, a large knob is shown on the "hand span" dial. This is not included in the parts list and I cannot determine how it is secured. Please advise.

Another minor point – while the majority of critical parts have company/part number listed, the speaker and potentiometer (R2253?) do not. (N. U., Strathfield, NSW)

● The speaker John used was a Jaycar part, catalog code AS3008. Some parts that Jaycar sells under that catalog code look different (they have a rectangular surround) but they still fit the PCB. The knob is Jaycar Cat HK7011. It has been glued on to the dial.

The reason that a specific part number was not given for the speaker is that there are numerous speakers that could be used from various sources but the Jaycar part is definitely suitable. Altronics Cat C0616 or C0626 look like they will also fit but we haven't tried them.

The potentiometer is a generic part so should not be difficult to find. For example, Jaycar RP7610 could be used, or Altronics R2253.

Building a Wideband Oxygen Sensor display

I was thinking about building the Jaycar KC5486 Wideband Fuel Mixture Controller kit. I believe it is based on one of your designs. The problem is that they have discontinued the Wideband Sensor Display kit (Cat KC5485). Is there a different display that I could connect to the controller? (P. A., via email)

● The KC5485 kit was based on one of our older designs, the November 2008 Wideband Air-Fuel Mixture Display (siliconchip.com.au/Article/2004).

This simply takes the 0-5V output signal from a Wideband Controller and converts it into a ratio value to display, as well as showing the raw reading as a bar/dot display.

We can supply a programmed PIC for that project (SILICON CHIP Online Shop Cat SC1286) but we do not have any PCBs. You would have to etch your own, using the PDF pattern (Cat SC1306).

We suggest that you instead build the display from our more recent Wideband Oxygen Sensor Controller Mk2, described in the June-August 2012 issues (siliconchip.com.au/Series/23). This should be compatible with the older controller and the PCB (SC0666) and programmed PIC (SC0761) are available from our Online Shop.

Commercial 0-5V wideband displays are available, however, they are quite expensive; from about $160 up to over $500!

You may want to build the Mk2 controller as it uses the superior Bosch LSU4.9 sensor and also includes the option for sensing exhaust gas pressure. We can also supply the PCB (Cat

High mains voltages causing equipment damage

I have been having trouble with some of my electronic devices. Some ICs in my Sony amplifier failed recently and a two-year-old Panasonic PVR has also malfunctioned.

I suspect that both are related to the mains voltage supplied to our house. Generally, it is above 250VAC. This morning, I measured it as 254V with a multimeter, 252V with a Powermate Lite and 248V with a True RMS multimeter.

Can you suggest a simple way of regulating the voltage to my electronic devices so as to keep the voltage around 230V?

I was considering some sort of voltage-sensing device which switched in and out a resistive load, however, I am not sure whether this would be practical. (B. D., Mount Hunter, NSW)

● This problem is now very common, with rooftop solar power generation boosting the mains voltage above 250VAC during the day.

While using a regulated AC mains supply would be the ideal solution, they are very expensive. A simpler and much cheaper approach is to use a step-down autotransformer to reduce the incoming mains voltage down to about 220VAC.

This entails wiring a transformer with a 30V secondary winding so that it is connected as a 250V to 220V autotransformer. We showed how to do this with the Mains Moderator project in the March 2011 issue.

We used a multi-tapped 60VA transformer from Jaycar, Cat MM-2005. If you want to use a bigger transformer, consider this 100VA unit from Altronics: Cat M2170L.

You can see a free preview of the article at siliconchip.com.au/Article/938

By the way, since the Australian mains standard is 230VAC+10%/-6%, technically any voltage in the range of 216-253V is considered acceptable.

Unfortunately, as you have discovered, many components designed for 230/240VAC are rated up to 250VAC, although 275VAC-rated devices are becoming more commonplace.

Super-7 AM Radio coil colours

I am building the Super-7 AM Radio project from the November and December 2017 issues.

I purchased the coil pack from Jaycar, Cat LF1050, to obtain transformers T2-T5. The pack contains four transformer coils, colour coded red, white, yellow and black.

The circuit diagram on pages 48 and 49 of the November 2017 issue calls for T2 to be red, T3 and T4 to be white and T5 to be black. Can I use the yellow IF coil supplied in the pack for T4? (P. V., Tarneit, Vic)

● You could do that but it may reduce the performance of the radio's IF section and therefore its overall performance.

It would be better to buy two LF1050 packs from Jaycar so that you have white coils to use for both T3 and T4.

SC0667) and programmed PIC (Cat SC0760) for this unit. The rest of the parts can be obtained from Jaycar/Altronics and the suppliers listed in the parts list.

You would also need a copy of the relevant articles for the parts list (June 2012), assembly instructions (July 2012) and installation/operation details (August 2012).

Modern TVs lack analog outputs

I am about to buy a new TV, but those that I've considered don't have the red & white RCA sound output sockets, for connecting to external amplifiers/speakers, as with my old TV. Can this situation be overcome without going to a completely new sound system? (I. S., Glenhaven, NSW)

● Provided your smart TV has TOSLINK or S/PDIF (coaxial) digital audio outputs, the easy way to get the left and right audio outputs is to obtain a DAC module. Jaycar have several, eg, Cat AC1715 or AC1633. They are featured on page 451 of the 2018 Jaycar catalog.

Alternatively, if you want true hifi sound quality, you should consider building one of our DACs, such as the CLASSiC DAC (February-May 2013; siliconchip.com.au/Series/63).

Battery and cell tester wanted

I am wondering whether there has been a project design for intelligently testing dry cells (and/or rechargeable NiCad/NiMH cells) for their current state; something more accurate than just a voltage check. I always seem to have AA and/or AAA cells lying around in piles and I don't know whether they are good or not.

The commercial chargers that I have are not intelligent and only light a red LED when a cell is being charged and a green LED when doing a pre-discharge. They have no end-of-charge indication or an accurate cell status display.

What I would like is something like the C-Tech 5-10 stage AGM/Calcium automotive battery charger but designed specifically for small cells. It would certainly be suited to a microcontroller project and would not be all that complex, I suspect.

Thanks for a great magazine! (C. T., Sunnybank, Qld)

● We have published a few battery and cell testers in the past. The only way to accurately know the current cell or battery state is to have a continuous monitoring of both charge (if rechargeable) and discharge and then, based on the capacity of the cell or battery, determine the remaining capacity.

Even so, this can be inaccurate due to internal leakage and an actual capacity that can differ between individual cells.

This method was used in our High-Current, High-Voltage Battery Capacitor Meter project (June-July 2009; siliconchip.com.au/Series/44). That project is now quite old and we are hoping to publish a new design relatively soon.

The other method for checking cell condition, other than simply monitoring the voltage, is to draw a certain amount of current and see how that affects the battery voltage.

Your enquiry does raise an interesting idea to have a cell/battery tester that can test the voltage using a pulsed load so that the current condition can be checked, even if the state of discharge can only be roughly gauged.

You may wish to read our reviews of the CBA IV Pro Battery Analyser in the February 2015 issue (siliconchip.com.au/Article/8308) and the Cadex C7400ER-C Analyser in the March 2014 issue (siliconchip.com.au/Article/6933). Also, see to the August 2009 Lead-Acid/SLA Battery Condition Checker project (siliconchip.com.au/Article/1535).

Problems getting Q-Factor Meter to work

I am having some trouble building the Inductance & Q-Factor Meter project from the February & March 2005 issues (siliconchip.com.au/Series/85).

On the circuit diagram on page 67 of the February issue, pad number 7 of the keypad is connected to the +5V rail but on the board, it goes to pin 11 of the micro. Which is correct?

I checked all the voltages by following the testing procedure and it is all OK. I was able to program the chip using the HEX file but I can't compile the v1.1 ASM file using AVR Studio 4. The error I get is "p9.asm(1440): error: .def: n2 redefinition".

Also with the AT90S2313 which I bought, the programmer is stating that its an ATtiny2313; that is the ID that is reported by the software I used (avrdude). I have tried it with a few different programs, including AVRDUDESS and Khazama all report the same thing. This is weird as it definitely labelled AT90S2313.

Can an ATtiny2313 be used with this project? I did set the "fuse" on the ATtiny2313 to allow for a 10MHz clock input at pin 5, which was not required with the AT90S2313. To do this, I set the lower fuse byte to 0xE0.

The Q-Factor meter was designed to use a Dick Smith LCD which is no longer available. I'm using a standard 16x2 alphanumeric LCD with no backlight. All I get on the display are black bars. Do you think it may be an LCD compatibility problem? (E. J. B., Bridgetown, WA)

● Pad 7 of the LCD is connected to pin 11 of the micro, while pad 7 of the keypad connector goes to the +5V rail via a 4.7kΩ resistor, as shown in the circuit diagram. We think the problem is likely a short circuit from the solder joint on the 4.7kΩ resistor from keypad pin 7 to the adjacent pin 7 pad on the LCD connector.

The pad is very close to the track and a short circuit there would pre-

vent the LCD from working. As far as we can tell, the typical 16x2 alphanumeric LCD available today should be compatible with the Dick Smith part.

It's very strange that you have a chip labelled AT90S2313 that is identified as ATtiny2313. The ATtiny2313 is the successor to the AT90S2313 but they are certainly not the same chip. For a list of differences, see: siliconchip.com.au/link/aake

The code should work on the ATtiny2313 but as you remark, the fuses will need to be set correctly. The fuse byte value you've used seems correct.

As for your inability to compile the ASM file to HEX, it looks like the error is due to a difference in the assembler between the one that Leonid used back in 2005 and the one you are using now.

He has two different items in his code called n2, one label and one "define". Apparently, the compiler he used was OK with that but the one you're using now insists that they have different names.

We suggest that you modify the labels in the bin_float routine to solve this. Change the line which reads "n2: breq n1" to "nn2: breq n1" and then change the line which reads "rjmp n2" to "rjmp nn2". That should allow you to compile it with the latest version of AVR Studio (which at the moment is v5.1).

Sourcing Currawong output valve sockets

I am trying to build the Currawong Stereo Valve Amplifier (November 2014-January 2015; siliconchip.com.au/Series/277), and have sourced virtually all of the components needed, however, one part I am having trouble finding are the valve bases for the 6L6 valves.

I already have suitable sockets for the 12AX7 valves but can't find the type I need for the 6L6 valves; the ones I bought have the mounting bracket facing the wrong way and the pins are not angled correctly to fit into the holes on the PCB.

It says in the text that the bases used are chassis-mounting, which are what I have purchased. The PCB mounting type apparently does not have mounting brackets which can be screwed to the PCB. Could you suggest where I could purchase these as I have all the other parts already? (B. H., Hunstanton, UK)

- Altronics have them listed in their catalog, Cat P8501 (page 319 of their 2018 catalog). See siliconchip.com.au/link/aakc You can download page 319 from that link and it lists their full valve line-up. The sockets you have purchased sound like the ones that Jaycar sells (PS2080) which are not compatible with the Altronics parts.

Since you're in the UK, you could also buy the sockets from: www.watfordvalves.com/product_detail.asp?id=4757 or www.karltone.co.uk/valve-tube-sockets-79-c.asp

We decided to use the Altronics-sourced sockets because ceramic valve bases have superior properties to thermosetting plastic sockets and the ceramic sockets have pins angled to allow for much larger separation between the PCB pads and tracks, which is important given the high voltages across them.

Inconsistencies in PICAXE dev system

I have purchased a Microchip PICkit 3 and your CP2102-based USB/TTL serial converter and I am now about to purchase the Oatley Electronics kit for the PICAXE USB Development System featured in the July 2010 issue of

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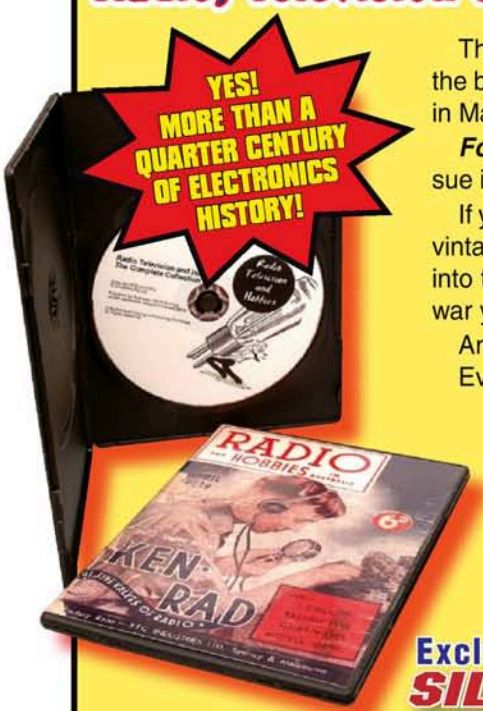

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your magazine (siliconchip.com.au/Article/218).

But I was puzzled when I saw the data sheet for the NEC 2SK3812 Mosfet specified for that project. It has a truncated drain (middle) pin.

How do you actually physically attach that little stump to the through-hole pads on the Development Board? What is the reasoning behind that when you need the three connections?

The photographs in your article and on their website show a three-lead TO-220 device on the board. It looks quite different to the 2SK3812 shown in the data sheet. What's going on? (B. T., Rosebud, Vic)

● That's a real head-scratcher. The 2SK3812 specified in that project is clearly a surface-mounting (only) Mosfet in a TO-263 (D2PAK) package. But the photos and diagrams show a different Mosfet was used, in a TO-220 through-hole package.

The middle lead of TO-252 (D-PAK) and TO-263 (D2PAK) SMD packages is truncated since that connection is made via the large tab which also provides the thermal connection to the PCB. This is similar to a TO-220 package, where the tab is electrically connected to the middle pin, but the middle pin is left intact for vertical mounting (which is not possible with an SMD).

Clearly it is difficult to solder an SMD Mosfet to pads designed for through-hole types. It would be logical if the board supplied with the kit had a dual-purpose through-hole/SMD mounting arrangement but that certainly is not shown in the artwork that we were provided for the article.

Assuming the board you receive matches what we published, it would probably easier to just get a suitable through-hole N-channel Mosfet in a TO-220 package (eg, STP16NF06, Jaycar Cat ZT2277) and use that instead.

Frypan heat controller and pump monitor

Congratulations on 30 years of SILICON CHIP magazine. It's a great achievement. I enjoy the breadth of coverage provided by the magazine and wish you continued success.

I would like to know whether any of the PWM/speed controller projects you have produced is suitable for controlling the temperature of an electric frypan.

While our frypan has a thermostat, this is a rather rough temperature regulator – it turns on and boils the living daylights out of whatever is in the pan and then turns off and sulks for awhile until things cool right down.

What I would like is a box I can plug into the wall and set it to the desired power. The electric frypan would then be plugged into it. The thermostat on the frypan would be permanently turned on full but the temperature would be regulated by the external box.

For example, if I wanted a low heat I would set the box control to around 25%. If I wanted a high heat I would set it to 100%.

I bought something like this for a Birko I had many years ago but I have lost it and I think it was only rated to about 1000W so would not be suitable for an electric frypan.

Another project I think would be useful would be a device to sense when a motor is on or off. We live in a rural area and rely on pumping from a creek (and the infrequent rain) for our domestic water. The creek is about 100m away and the electric pump is down there.

The pump has a pressure vessel which is intended to reduce the number of times the pump turns on by providing water from the pressure vessel until the pressure drops below a set value at which time the pump kicks in. When the pressure in the pressure vessel is above a set value, the pump turns off again.

Some time back, the foot valve managed to detach itself from the poly pipe. This meant the water from the pressure vessel rapidly discharged through the poly pipe back into the creek. The pump would then fire up and pump it back into the pressure vessel then turn off and the cycle would repeat every few seconds.

I am not sure how long this went on for as the pump is very quiet and some distance from the house. It should be possible to design a sensor (eg, using a coil of wire wrapped around the mains

MPPT Solar Charger may not function with small panels

I have just finished constructing the Solar MPTT Charger and Lighting Controller kit from Altronics (K6027) based on your February and March 2016 publications (siliconchip.com.au/Series/296).

While it appears to be functioning correctly for the most part (ie, it's charging the battery with the BULK LED solidly lit and flashing at a half-second interval for absorption phase etc), I am not convinced that the MPPT component is functioning correctly.

My test set-up involves a 40W solar panel feeding an 18Ah 12V SLA battery. With the battery voltage down so the charger is in BULK charging mode, when I measure the voltage across the solar panel it is only about 0.4V higher than the battery voltage.

For example, the battery voltage may be 13.2V with the solar panel at 13.6V (measured at CON1).

This is with the panel in full (near midday) sun, with a measured current to the battery of ~2.2A. I was expecting the solar panel voltage to be more like 17V as per the article.

It seems like Q1 is simply switched on fully and I am just measuring the voltage drop across it and D1. I have checked for shorts etc on the board but it all looks OK.

Is there some way that I check the operation of the MPPT component of the controller? Do I need to change my test set-up? (P. B., Capalaba, Qld)

● If the MPPT charging was working then the solar panel would be at around 17-18V. To make the best use of the MPPT feature, you need to use a 100W or 120W panel, not 40W.

That's because MPPT charging is optimised for the higher current available from the larger panels. At 40W, the inductance of L1 is not sufficient.

So for the 40W panel, you may need to add more turns on inductor L1. Four times as many turns should allow the MPPT switching function to work.

Note that the Jaycar LF1272 or Altronics L6522 100µH 3A choke could also be used instead.

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cord) which detects when current is being drawn and transmits a signal to a remote receiver which could turn on an indicator.

If the indicator cycled on and off more than a set number of times in a set period, it could sound an alarm. Something like this would be very handy for checking whether remote equipment is operating or not. (M. B., Woodford, Qld)

● To control the temperature of your electric fry pan, our April 2018 230VAC Thermopile-based Heater Controller design would be suitable, built as the simpler 0-100% control version (ie, without the thermopile). This will handle loads of up to 2300W (ie, drawing 10A from the mains). See siliconchip.com.au/Article/11027

To prevent your pump from running incessantly if there is a leak, you could use our Cyclic Pump Timer project, which was published in the September 2016 issue (siliconchip.com.au/Article/10130). It monitors the pump run time and switches it off if it runs for too long.

Note that the 10µF current monitoring filter capacitor (connecting across ZD1) may need to be increased to 100µF to maintain a motor current reading when the pumps switches off momentarily during its rapid on-and-off cycling, due to the presence of the pressure bladder.

Differential temperature controller wanted

I have been going through all my old SILICON CHIP issues to see if you have had a Proportional Solar Pool Temperature Controller project.

I need a unit with two temperature sensors, one for the solar water collector and one for the pool. It should be able to set the temperature with a variable control and control a relay for the 230VAC pump.

I have a Tempmaster Mk2 which I built from the February 2009 issue (siliconchip.com.au/Article/1337) and I have seen that you published a Tempmaster Mk3 in the August 2014 issue (siliconchip.com.au/Article/7959).

Could any of these be modified to have another temperature sensor input? (R. S., Epping, Vic)

● Yes, it would be possible to modify the Tempmaster Mk3 to make it respond to the difference in temperature between two sensors, however, it isn't a proportional device. It simply switches a relay on and off.

You could do this by wiring a second LM335Z temperature sensor between pin 1 of LK3 and GND. That would make the reference voltage proportional to the temperature of the second sensor, as long as it is below 45°C.

You could then arrange for the output to switch on when the temperature at one sensor is above or below the other, or even offset by several degrees, depending on the settings of LK1-LK4 and trimpot VR1.

For example, by bridging pin pair 1 of LK3 and LK4 and putting LK1 and LK2 in the Cold (C) positions, you could adjust VR1 so that the output switches on when the temperature of TS1 is higher than that of TS2. Or you could use the same configuration but with LK1 and LK2 in the Hot (H) positions, the output would be on when the temperature at TS1 is lower than that of TS2.

Incidentally, we are in the process of designing a DC fan/pump controller which should be capable of proportional and on/off control of multiple devices based on the temperature difference across two sensors. That should certainly suit your needs; it could be configured to drive the coil of a mains-rated relay to switch the 230VAC pump.

Temperature Switch Mk1 kit failure

I have just connected one of your Temperature Switch kits (January 2007; siliconchip.com.au/Article/2109) to operate in conjunction with a smoke detector and PICAXE microcontroller, to start a water pump with a sprinkler to protect our house in a bushfire-prone area.

I tested the setup by turning on LED lights in lieu of starting the pump and all went well. However, when I connected up the pump, the 10Ω resistor at the 12V input started smoking after about 30 seconds. The 12V supply is from a sealed lead-acid battery with a 10W solar panel maintaining charge.

Being a sunny day and not having a regulator for the solar panel, the battery voltage was around 14V but that shouldn't have been a problem. I thought possibly the water pump may have sent a higher voltage but the battery should have soaked that up.

I tried measuring the voltage with the pump running this morning and it was below 12V, due to engine cranking and a cloudy day.

The resistor still reads 10Ω so I tried connecting the power again but it started glowing red hot after a few seconds, with less than 12V across the battery. Any suggestions you have would be greatly appreciated. (G. L., via email)

● We suspect that 16V zener diode ZD1 has failed short-circuit. This was probably damaged due to excessive voltage transients from the pump motor.

To protect the zener diode, power for the temperature switch power should be taken directly from the battery using separate wiring (ie, not the same wiring used to power the pump).

You could beef up the supply filtering by using a 47Ω 1W resistor in place of the 10Ω resistor and a 5W zener diode such as the 1N5352B (Jaycar ZR1450) for ZD1. This is rated at 15V instead of 16V but it would do the same job.

Power transformer for the CLASSiC-D

I have assembled the Jaycar KC5514 Class-D amplifier kit, based on your CLASSiC-D design from the November and December 2012 issues (siliconchip.com.au/Series/17).

I'm about to start on the corresponding KC5517 power supply kit but I noticed that on its packaging, it says that the kit requires "Centre tapped transformer(s), 40V+40V for the ±55V rails (amp) and 15V+15V windings for the auxiliaries".

I shot down to my local Jaycar store to pick up a transformer and also the 35A/600V bridge rectifier but I couldn't find either.

The staff at the store suggested that I contact you and ask if you have Jaycar part numbers for those two items. (M. H., via email)

● The recommended transformer is the Altronics M5535A. This has 35V windings and will give a nominal ±55V supply, dropping to 50V under the full 300VA loading. Jaycar does not have a suitable transformer for this project. The bridge rectifier catalog codes are Altronics Z0091 or Jaycar ZR1324.

Alternatively, you can use a 35-0-35V transformer with a lower VA rating. You would need to wind on your own 15V windings on top of the ex-

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isting ones, or use a separate 15-0-15V transformer.

Testing optocoupler in MPPT Charger

I built the Solar MPPT Charger & Lighting Controller from the February and March 2016 issues (siliconchip.com.au/Series/296) and tested it but the 4N28 optocoupler (OPTO1) does not seem to be working. I measured 4.8V at pins 1 and 2 and 12V at pin 5 but 0V at pin 4 so suspect it is faulty.

Can I use a 4N25 instead as I have a spare one? If so, would I need to change the circuit? (E. B., Bridgetown, WA)

● A 4N25 can be used in this circuit without changes. However, based on the voltage measurements you have supplied, it does not seem that the 4N28 is faulty.

If you measure 4.8V at both pins 1 and 2, that means there is no current flowing through the optocoupler LED and thus you would expect a low voltage reading at pin 4.

Check the soldering and parts placement on your unit before deciding if OPTO1 is at fault. Also, note that the optocoupler is only switched on when Q5 is on (via gate drive from RB5).

In this case, pin 2 should be around 3.8V, ie, around 1V between pins 1 and 2. We suggest you re-check the voltages on the pins of OPTO1 when S1 is pressed. This switches on the optocoupler. SC

Coming up in Silicon Chip

Differential GPS (DGPS)
This system provides precise location and distance measurements in a 3D space with accuracy down to about 10cm, compared to an error measured in metres for standard GPS receivers. We take a look at the technology involved and some of the real-world applications for it.

Four-channel DC Fan and Pump Controller
An updated speed controller for DC fans and pumps which runs from a 12V supply, can switch up to 40A of fans and/or pumps based on temperatures from up to four sensors. It's configured over a USB interface and can also provide real-time feedback on its operation.

PICkit 4 Review
Tim Blythman takes an in-depth look at Microchip's new in-circuit programmer and debugger for PIC and AVR microcontrollers. He has been using it extensively for testing and debugging PIC32 software and reports on his experiences. **Super Digital Sound Effects Module, Part Two**
The second article has the construction details along with detailed information on how to configure and use our new Sound Effects module.

Note: these features are planned or are in preparation and should appear within the next few issues of Silicon Chip.

The September 2018 issue is due on sale in newsagents by Thursday, August 30th. Expect postal delivery of subscription copies in Australia between August 28th and September 13th.

Notes & Errata

Philips Compact Cassette and EL3302 Cassette Recorder, July 2018: at the top of page 28 it states that the EL3302 had a battery comprising five AA cells but as shown in the schematic on page 30 (Fig.5), it actually used five C cells.
Super-7 AM Radio, November & December 2017: the parts list includes four 22nF MKT polyester capacitors and one 47nF MKT polyester. It should instead list five 22nF capacitors and no 47nF capacitors.
New SC200 Audio Amplifier, January-March 2017: The circuit diagram for the SC200 shows a 150Ω resistor in series with VR1. This should be 120Ω to match the overlay diagram and parts list. Also, the overlay diagram shows a 100pF 250V capacitor; this should be 150pF 250V as shown in the circuit diagram and parts list. The PCB has the correct markings.

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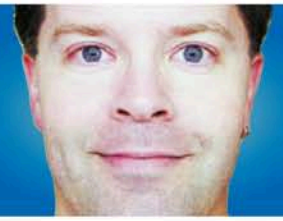

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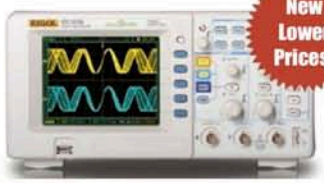

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Metric HSS Combination Tap & Drill Set

- 7 piece set
- Designed for up to 3.2mm sheet metal
- HSS M2 grade
- M3, M4, M5, M6, M8, M10
- Includes hex snap-on drive

$56 ~~$66.55~~ (T0191)

HSS Countersink Set

- 6 piece set
- HSS M2 grade
- 45° angle
- Ø1.5 ~ Ø6.3mm
- Ø6.3 ~ Ø8.3mm
- Ø8.3 ~ Ø10.4mm
- Ø10.4 ~ Ø12.4mm
- Ø12.4 ~ Ø16.5mm
- Ø16.5 ~ Ø20.5mm

$66 ~~$82.50~~ (D1061)

Metric HSS Hole Saw Set

- 11 piece set
- M42 Bi-Metal high speed steel
- 19, 22, 25, 32, 35, 38, 44, 51, 57, 64, 76mm
- Includes 3/8" & 1/2" arbor shank & pilot drill

$89 ~~$110~~ (D102)

EF-5S - Engineers File Set

- 200mm hardened and tempered files
- Second cut: Flat, 1/2 Round, Round, Square, Triangular
- Includes carry case

$29 ~~$42.35~~ (F100)

HS-2S - Throatless Hand Lever Shear

- 1.2mm mild steel capacity
- Cast steel construction
- Tool steel quality blades
- Gear drive shearing action

$231 ~~$275~~ (S184)

DB-180 - Digital Bevel Box

- 180° range
- Auto shut off
- Magnetic base
- 0.1° resolution

$55 ~~$77~~ (M977)

Digital Caliper

- 150mm / 6"
- Metric, inch & fraction
- 4-way measuring
- Includes battery

$29 ~~$38.50~~ (M738)

Alloy Steel Tap & Die Set

- 32 piece set
- M3 ~ M12 alloy steel
- Includes button die holder wrench, tap wrench, screw pitch gauge, screwdriver

$60 ~~$71.50~~ (T012)

Alloy Steel Tap & Die Sets

- 45 piece set
- Metric or Imperial fine & coarse set
- M6 ~ M24 alloy steel (T014)
- 1/4" ~ 1" alloy steel (T015)
- Includes die holder & 2 x tap wrenches

Metric **$153** ~~$180.40~~ (T014)
Imperial **$153** ~~$180.40~~ (T015)

ALL THIS & MORE IN STORE & ONLINE

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TCS-3 - Mobile Tool Cabinet Seat

- 3 x drawers with ball bearing slides
- 420 x 235mm padded seat
- 2 x magnetic side trays
- 406mm seat height
- 360° swivel wheels

$95 ~~$110~~ (A001)

BD-325 - Bench Drill

- 16mm drill capacity
- 2MT spindle
- 12 spindle speeds
- Swivel & tilt table
- 1hp, 240V motor

$299 ~~$330~~ (D590)

VIPER 150 - Multi-Function Inverter Welder-MIG-MMA

- 30 - 150 Amps
- 240V - 10amp
- Gas / gasless
- 15% @ 150A duty cycle

$440 ~~$473~~ (W245)

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Specifications & Prices are subject to change without notification. All prices include GST and valid until 30-08-18